# REFINER
## AND NATURAL GASOLINE MANUFACTURER

DECEMBER, 1934
Vol. 13, No. 12

*A Gulf Publishing Company Publication*
EDITED MONTHLY AT HOUSTON, TEXAS

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GEORGE REID
*Editor*


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SPECIALIZED OIL JOURNALS

*Published by*

GULF PUBLISHING COMPANY

OFFICE OF PUBLICATION
3301 Buffalo Drive, Houston, Texas

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A. L. BURNS, *Gen'l Manager*
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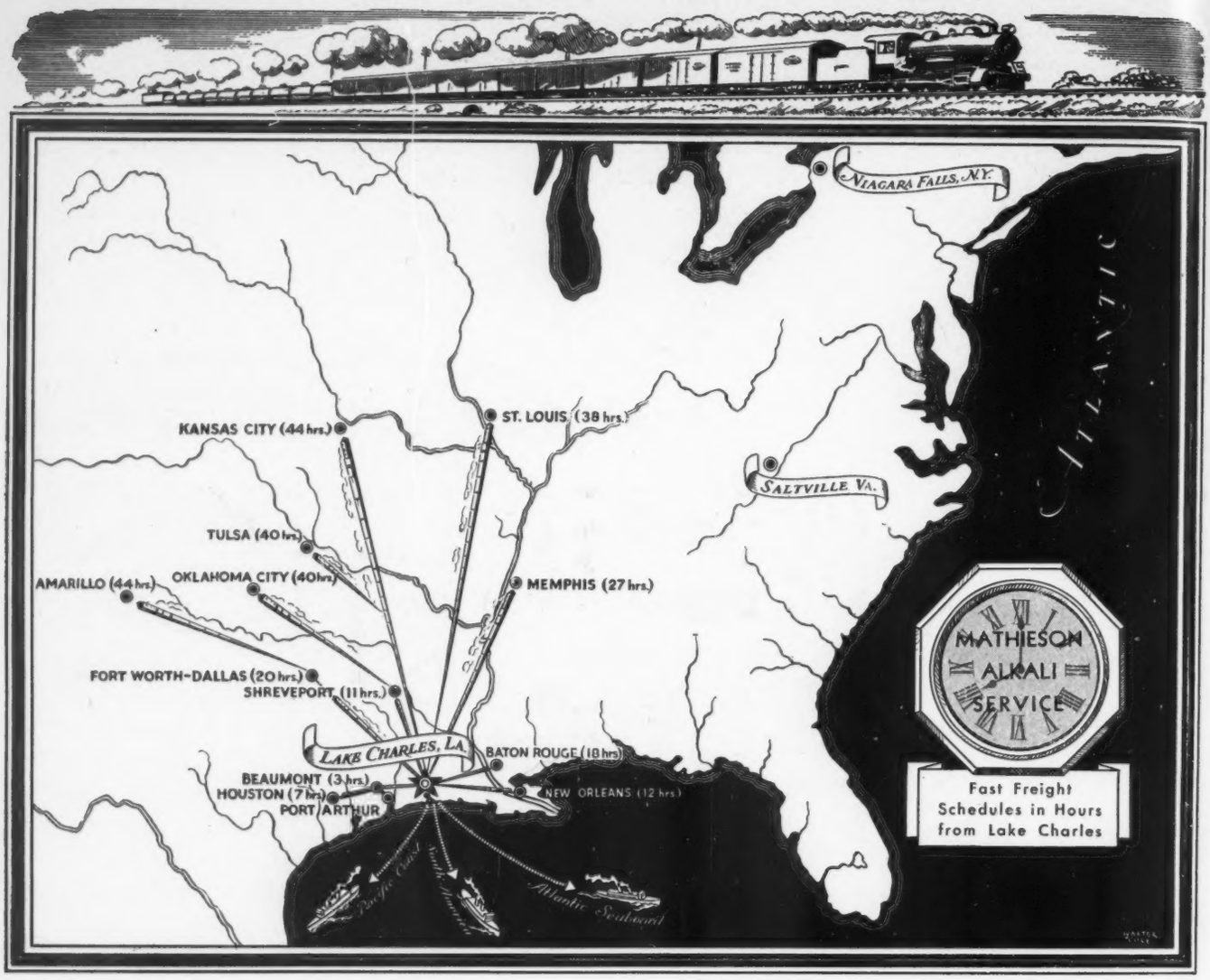
TULSA: 913-916 Hunt Building, J. F. Carter, Jr., Manager.

FORT WORTH: 203 W. T. Waggoner Building, H. H. King, Manager.

Single copies 20 cents. Domestic and Foreign subscription price, $1.00 a year. Entered as second class matter June 16, 1923, at the post office at Houston, Texas, under Act of March 3, 1879. Advertising rates on application.




# MATHIESON *SPEEDS UP*

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CONSUMERS throughout the Southwest can now get deliveries of alkali in a matter of *hours!* Beginning this month, Mathieson's plant at Lake Charles, Louisiana, offers this fast delivery service.

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*Mathieson Chemicals*

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REFINER
AND NATURAL GASOLINE MANUFACTURER
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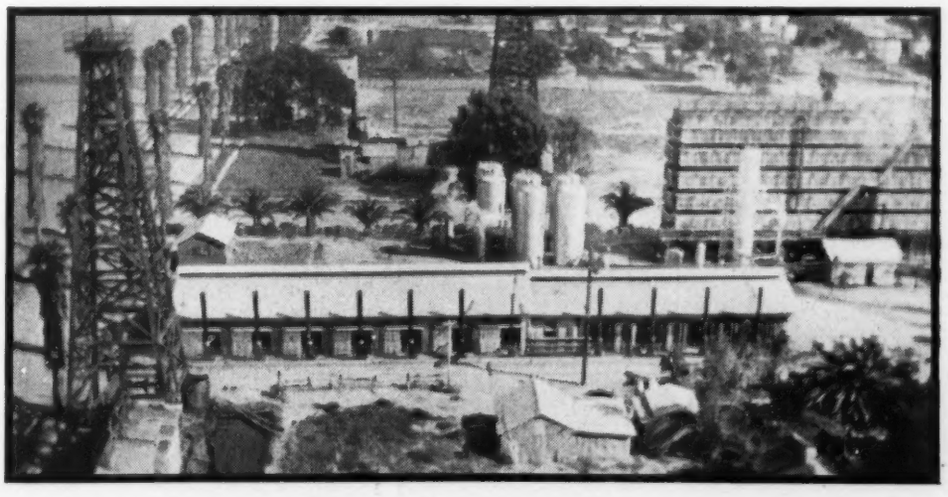
VOLUME 13, No. 12 DECEMBER, 1934

***Solvent Refining*** Adoption of solvent refining and solvent extraction processes in the manufacture of lubricating oils has progressed during the year with a larger number of actual installations than was expected by many. It appears now that solvent processes will be used by the industry in a much greater number of actually operating plants by the middle of 1935 than was once thought would be the case by the middle of 1936. The number of companies now operating such units, now building processes and soon expected to announce their plans indicates that the refiner without solvent refining or extraction facilities had better cease wondering if such facilities should be installed, and get into the frame of mind to make an early selection of one or more processes and soon begin actual construction. By the end of next year all nationally advertised and distributed motor lubricating oils are geing to be of the solvent treated type—that is the handwriting on the wall.

***Politics*** One very definite fact was established as the result of the general elections early last month. One school of opinion held before the elections concerning the extent of the national approval of President Roosevelt's policies was routed. This one held that the election would show sufficient loss of congressional representation by his partisans as to provide indication that the administration's courses were not entirely approved. Another school of opinion accepted and advocated continuation. The latter has been unquestionably sustained and in remarkable degree.

Since Mr. Roosevelt has been approved, those in business and industry who have been waiting for a decision on that point, now know exactly "where they are at." As to how such a decision affects the conduct of men and as to how their conduct affects business there are precedents to consult. Past experience shows that those people who have been hesitant about investment, about business policies, expansion, modernization of manufacturing facilities, while waiting for changes in governmental policies to better suit them, have virtually always accepted the inevitable when final decision was adverse and proceeded to make the most of it.

It is only American, or peculiarly American, especially among business men, that the game can be played, aggressively and fairly, whatever may be the rules, once the rules are established. It is the uncertainty about the rules that contributes to prolonged hesitancy. Already, since election, the decision has been accepted, and knowing the rules, much has gotten under way, more has been announced, that indicates the readiness of industry to forge ahead. In petroleum refining circles some important activities have come about and more, much more, will soon follow.



***Taxes and Earnings*** During the past five years, taxes on the petroleum industry, federal, state, and local, have risen to a point where its billion dollar tax bill last year amounted to five times the earnings of the industry, figures compiled by the American Petroleum Industries Committee, New York, show.

In 1929 the industry earned approximately $456,000,000 and paid taxes of $625,000,000. The next year net earnings dropped to $92,000,000, while taxes rose to $670,000,000. The following two years the industry operated at a loss while its tax bill continued to climb. Last year, although the deficit was eliminated, taxes jumped to over a billion dollars, five times the net earnings of the industry, when $1.11 were paid in taxes on each barrel of crude oil and its derivatives. Its total tax bill amounted to $1,004,824,028, while earnings were $204,000,000.

Published earning figures of another representative industry, railroad transportation, also shows an increase in the ratio of taxes to earnings during the past five years, but its tax bill was less than earnings (53.7 percent). This industry earned $474,000,000 and paid taxes of $255,000,000 last year.

Taxes must be kept in line with earnings or consumption will be discouraged—and both industry and government will find themselves around the corner from prosperity.

***Next Month*** Next month, January, 1935, THE REFINER begins Volume 14—and in this volume as in the past THE REFINER will continue to devote its work to the presenting of latest availaable information on egineering progress and technical development in refining of petroleum and manufacture of natural gasoline. Certain special issues to be announced later will bring together much valuable refining process development information and engineering and technical data which will prove of permanent value.

In January two new series of articles will start. W. L. Nelson will begin a series of three articles on Laboratory Evaluation of Oil Stocks: Part 1, Classification of Crude Oils and Methods of Distillation; Part 2, Typical Analysis and Evaluation Curves; Part 3, Evaluation of Lubricating Oils and Use of Replica Plants.

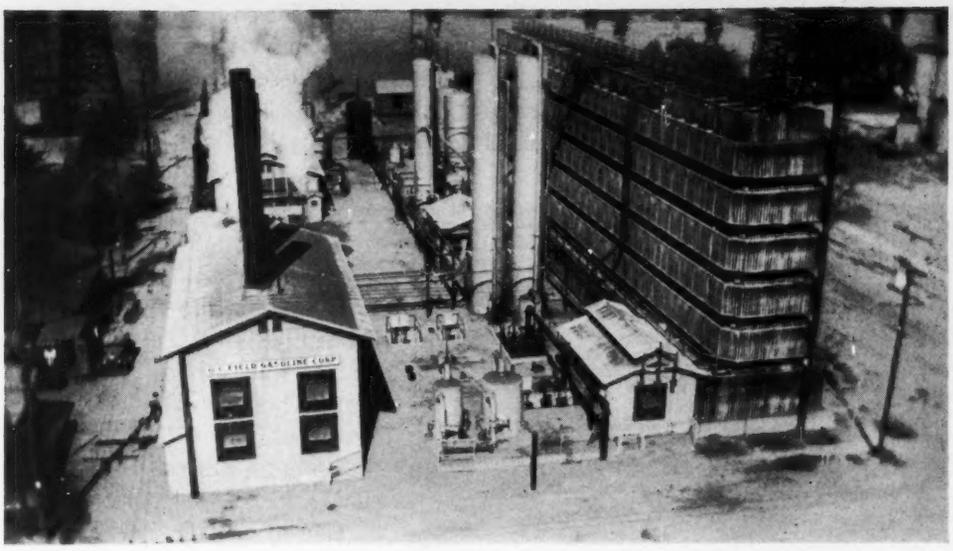
The second series is by R. L. Huntington and V. W. Garton, on The Efficiency of Petroleum Fractionating columns. Part 1 deals with capacity and efficiency of laboratory packed towers, and Part 2, with the efficiency of commercial bubble towers.

L. C. Trescott will be back with an interesting discussion of the salvaging of refinery wastes, and I. N. Beall, who has been absent for a few months, returns with Part 4 of his highly interesting and valuable series of articles on Elements of Stabilization.

Engineering descriptions of some new refining installations are also scheduled for publication in January.

***This Issue:*** Another of the latest gasoline producing plants on the West Coast, that of O. C. Field Gasoline Corporation, a new plant at Huntington Beach, is described. Some interesting construction anad operating methods are discussed . . . Three papers read before the annual meeting of the American Petroleum Institute are presented: W. K. Lewis, on the mechanism of viscosity, adds to the literature of that subject; Joseph Gesechelin, in his discussion of Diesel fuels, set at rest the ill advised opinion that Diesel fuels will shortly replace gasoline; T. G. Delbridge, chairman of the American Petroleum Institute Committee on Viscosity Standards, presents the report of that committee's work during the past few years and discusses future work . . . L. C. Trescott, in discussing control of costs, explains a lot of things in addition to why the master mechanic chews lots of "mailpouch" on the job, burns strong black pipes after hours; always carries a 24-inch pipe wrench and seldom cares to hear your funny stories. All will find that the seemingly dry subject of maintenance costs holds much of interest and value . . . B. R. Bay discusses compressor station problems from the viewpoint of site selection, design of plant, construction, auxiliary equipment and general operation problems. He knows his compressors and is well qualified to write about them . . . A description of a refinery specializing in manufacture of road oils in the Rocky Mountain district, and a description of design and operation of a continuous doctor treating plant with doctor solution regeneration equipment is included.

***New Equipment*** Rehabilitation and modernization of refining facilities have attained an importance equal to that of construction of new refineries. The progress in this industry during the past two years has been especially marked by the interest in the introduction of new and improved processes. The increasing demand for high grade motor fuel and lubricants, coupled with the narrowing of margins between crude prices and refined products are powerful factors bringing pressure toward greater efficiency. And efficiency can not be secured with old fashioned, worn out and unsafe refining facilities. Marked activity in modernization and construction of new facilities in virtually every department of the refinery is sure to come.



*O. C. Field Gasoline Corporation's Plant No. 4 at Huntington Beach, California*

# *Facilities for* Liquefied Gases *In Gasoline Plant Design*

J. C. ALBRIGHT

O. C. FIELD Gasoline Corporation, Los Angeles, constructed a new gasoline manufacturing plant in the summer of 1933, and added more compressors late in 1934. This plant was built to process the extra volume of gas made available during the drilling boom at Huntington Beach when between 55 and 60 wells were completed by directional drilling to a productive zone beneath the ocean. Approximately 70 percent of the gas made available by the drilling of the new wells was secured by the company, amounting to an average production of 60,000,000 cubic feet daily. To receive and process this gas, the new plant was constructed on a space 120 feet by 350 feet, requiring only 30 days from the time the first work was begun.

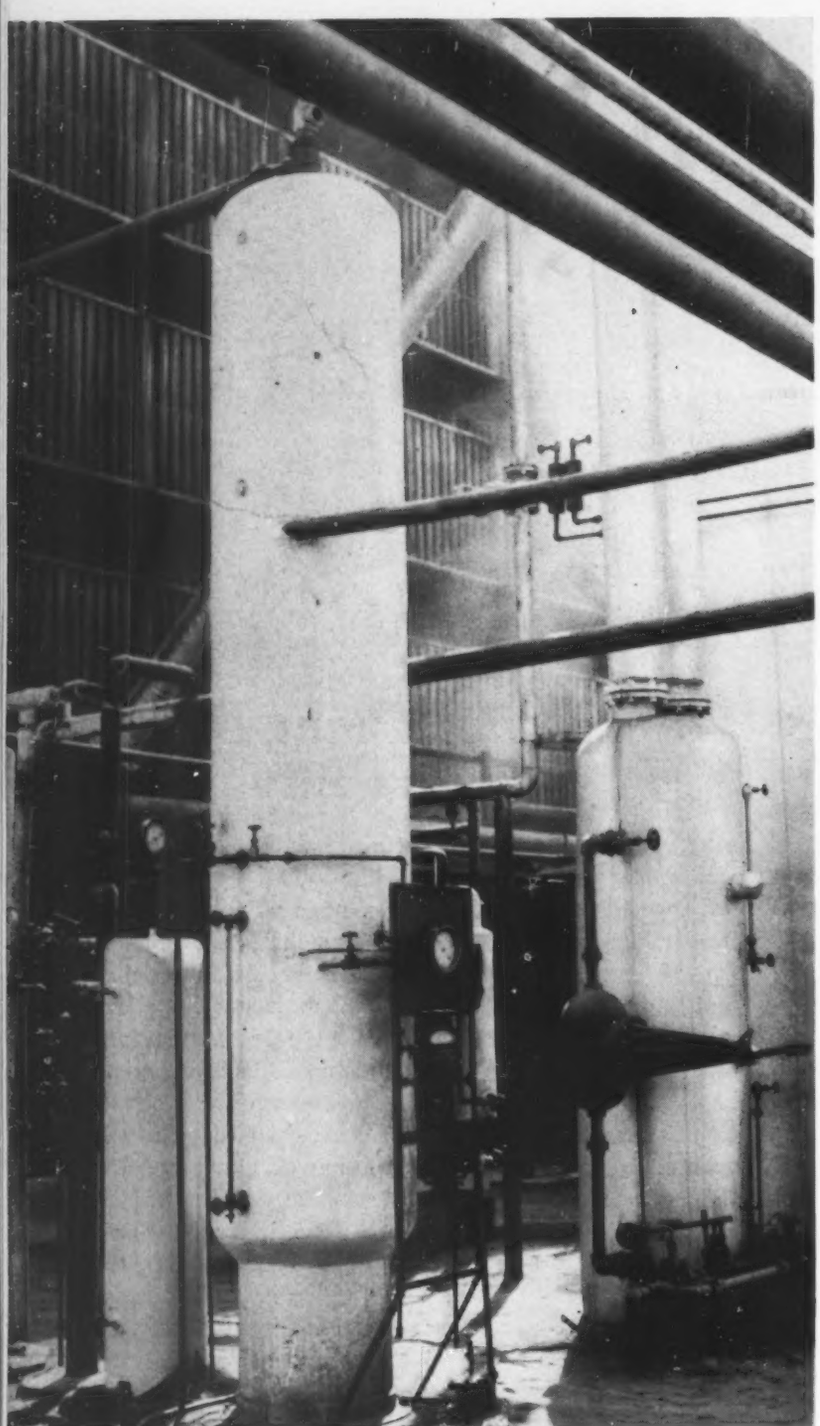
An average of about 30,000,000 cuibc feet of the flush gas from the new wells is processed through the new plant. It fluctuates from hour to hour and from day to day because of the restricted production rules. This gas is received from the field under modified well pressure through a complicated gathering system made necessary by pipe lines and connections laid during the past 12 years. The volume treated in this extraction plant is handled by six machines having 18 x 20-inch compressor cylinders, and four machines, fitted with 17 x 20-inch cylinders. The original equipment included only the latter machine, but when it was evident that the volume of gas would remain fairly constant, the six additional units were set up in the summer of 1934. These are equipped with gas injection power cylinder heads, and the compressor cylinders are equipped with heads having clearance pockets to compensate for load and intake pressure.

The machines receive the gas from a 16-inch intake header hung above the compressor cylinders at an average of 15 pounds intake pressure. The intake control and shut-off gates are placed on short nipples above the intake flanges, but the discharge gates were placed outside the building near the doors. Indicating pressure gauges have been installed for each battery of engines, mounted on separate boards, so that the operators can determine the condition of either battery. Lighting of the interior of the engine room is accomplished during daylight through a continuous sash extending the full length of the building set between the top of the doors and the eaves. Ventilation is accomplished through a continuous opening at the peak of the roof.

All of the 10 twin engines are fitted with air cooled exhausts and mufflers, that not only suppress the sound of engine exhausts but also prevent heating of the connections and stools. Water injection with this system of exhaust cooling and muffling is not required. The fuel required for the power cylinders of both batteries of engines is received in an overhead header and reduced to the required pressure through regulating valves, one of which is placed for each twin engine, and passed into individual receivers hung above the cylinders. The

gas enters these receivers at both ends and is taken from the center through a goose neck to the mixing valves and fuel injectors.

Cooling of both the power cylinders and the compressor cylinders of both batteries of engines is secured by positive circulation of treated water. The jacket water was prepared in the beginning by zeolite softening to approximately zero hardness and the closed system filled. The water is circulated by the use of both a steam turbine-driven centrifugal pump, directly attached to the shaft, and a gas engine-driven centrifugal, driven through a multiple V-belt drive. Make-up water is placed in the circuit from condensate received from steam used in various parts of the plant. Gas engine drive for this service has been found satisfactory and economical.



***Absorption Oil Cleaning Plant***

A lubrication system recently installed includes a central oil storage tank, operated under pressure, which directs the oil continuously to each of the several lubricators on the engines as well as to the crankcases. One main distributing line was laid on the girders above the engines with the individual distributing lines terminating in dust-proof sight feeds, where the quantity of oil necessary to replenish the lubricators is regulated. The actual lubrication of the various points remains as in the usual set-up, using force feed positive driven lubricators.

Gas at the discharge pressure of 45 pounds is led from the headers at the engine room to a battery of cooling sections where it is cooled. It is then introduced directly into two absorbers. Each of these units have 26 plates and the columns are seven feet in diameter by 60 feet in hight. After being stripped of the desired constituents while in contact with the absorpion oil, the gas is scrubbed and distributed at 35 pounds to the various points necessary for final disposition, either to the field, for fuel gas in the plant or to the intake lines leading to the industrial gas companies receiving gas from the field.

The absorption oil used in this plant is a low molecular weight product, acid treated, with a gravity of 41° A. P. I. The boiling range is between 360° F. initial and 490° F., end point. Circulation of this oil through the system is accomplished by a gang pump setting, having two centrifugal units on a common shaft. Each of these are capable of handling 600 gallons per minute at 2900 r.p.m. with 292 feet discharge presssure. The pumps are driven by a 125-horsepower steam turbine operated on 150 pounds steam with no preheat or back presssure. The unit is said to consume less than 65 pounds of steam per horsepower.

The rich oil pump takes the fat oil directly from the base outlet of the two absorbers at column pressure and discharges it at 95 pounds to a battery of four tube and shell heat exchangers. One steam operated preheater is used to prepare the oil for introduction to the still. Condensate in the prehater is trapped and led through an overhead line to the boiler make-up tank and feed water heater.

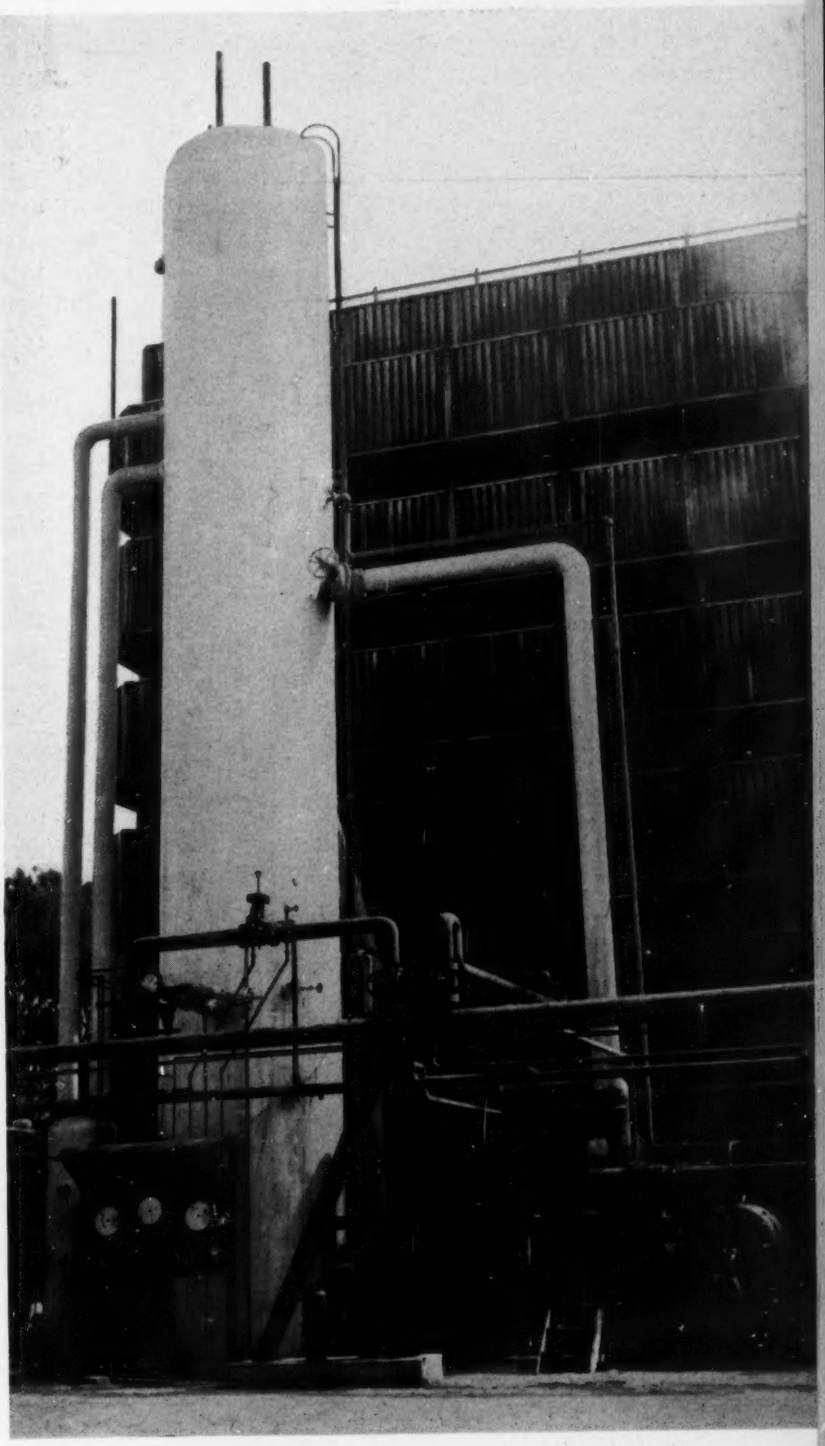
As the oil enters the fractionating evaporator it is at a temperature of 315° F. I is introduced to this column, which is 72 inches in diameter by 45 feet in height, above the tenth tray. The column has 18

plates, 13 of which are stripping-fractionating, and five purely fractionating. A new type water leg, or dehydrator, is built into the unit, taking condensed steam from above the thirteenth plate through an insulated line which leads downward (on the outside) to a collecting drum. The water, only, is removed through a trap, while the oil that may come over with it is returned to the top of he column through another insulated line. Each line stands full of liquid at all times during operation. Through this improvement, a great part of the condensed steam in the form of water is removed which assists in removing a useless load from the gasoline condensing and cooling sections in the louvre tower.

Vapors driven from the low molecular weight absorption oil, assisted by the introduction of live steam in the base of the fractioning evaporator, are controlled as to end point by the introduction of liquid reflux pumped back over the column. This reflux is at the rate of approximately 93,700 gallons per day, or a ratio of 3¼ to one. These vapors are removed from the top of the column through a bare line, bending downward to a low setting of two primary condensing sections. Each of these condensers have a surface area of 630 square feet each and are hooked up in parallel.

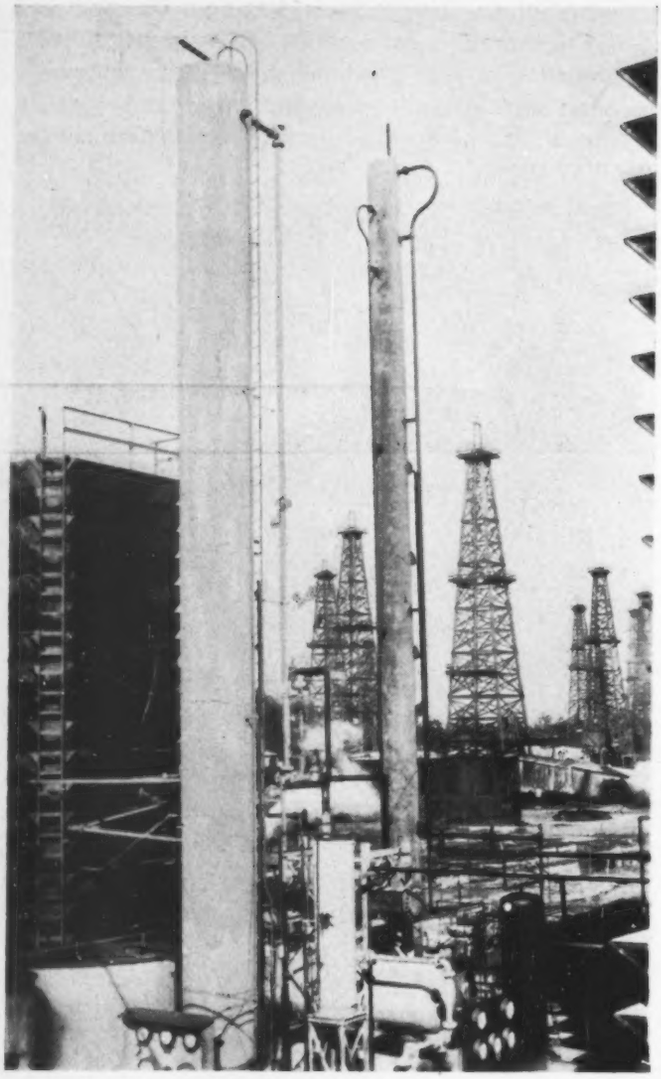
All of the condensate and uncondensed vapors enter a primary accumulator tank, from which the reflux is taken for still overhead control. The liquid necessary to maintain the proper balance is pumped by one of two simplex steam pumps, size 7x8x10-inch. The rate of flow is controlled by regulating the amount of steam entering the power cylinder. Control of this is obtained through a throttle valve placed in the steam line before it branches to each of the pumps. The valve is operated by temperature volume controller, maintaining the proper still overhead condition through the automatic operation of the pumps. Rate of reflux flow is measured and recorded through an orifice meter. Steam to the still for agitation and partial pressure control is also measured by an orifice meter.

After the vapors pass through the primary accumulator tank they are passed again through condensers. This secondary bank consists of two atmospheric type sections, each of which contains 630 square feet of cooling surface, but are connected in series. The surplus gasoline not needed for reflux together with the secondary condensate are trapped from the accumulator tanks under condensing pressure to the storage battery. This tank farm contains six vertical cylindrical vessels similar in construction to the usual horizontal units. Installation of these units was accomplished by pouring a flat concrete base almost flush with the ground level, then providing short rings upon which the tanks were placed, raising the lower heads a short distance from the surface of the concrete foundation.



***Fractionating Still and Heat Exchange System***

Several advantages are apparent in this type of installation, one of which is the small amount of room necessary for erection. Another is that gauging is more easily accomplished with vertical cylindrical tanks than with horizontal units, and is more accurate. Piping is not intricate in this type of installation. Charging and pumping out lines enter and leave the sides of the tanks in



***Fractionator Battery***

the same manner as if they were placed on cradles, while the vent lines through which the escaping vapors are removed are identical to those in other settings. Relief lines leaving the safety valves extend to a much greater height, and provide a more rapid diffusion of the escaping vapors before they have an opportunity to reach the ground and possible ignition.

The stripped oil leaving the still is reduced to two millimeters, at 100° F., and is driven under still pressure of 33 pounds through the heat exchangers on its return trip, from which it is picked up by the lean oil pump. This pump delivers the oil to a battery of cooling sections, having a total cooling surface of 5300 square feet. The oil is reduced in these sections to an average of 76° F. After passing through the cooling sections, the oil again enters the absorbers and completes the cycle.

The raw gas handled by this plant has a content of 1.25 gallons per thousand cubic feet as shown by a charcoal absorption test, and the distillation is carried out at 32° F., receiver temperature. A fractional analysis on a Podbielniak column shows there is a content of 1.15 of 22 pounds, Reid vapor pressure gasoline. The pentane factor of the plant is held at 1.3 which is sufficient to extract all of the available pentanes and heavier, while the butane factor is held at such a point that all of the essential butane is removed from the gas. More of the butane and lighter could be removed from the residue gas while it is in the absorber if it were necessary, but by removing only that which is essential to 22 pound Reid vapor pressure, and not permitting any of the pentane and heavier to escape an overload on the central fractionator at the company's plant No. 1 is prevented.

Fractionation control on the still is carried to such a point that the recovered distillate has an end point of only 290° F., comparable to compression gasoline in this respect, and also shows that all of the absorption oil has been removed from the vapors before they leave the fractionating still.

The cooling tower in which all circulating water and other materials are reduced in temperature is 23 feet in width, 174 feet in length and 54 feet in height, having 28 bays, handling 3000 to 3400 gallons of water per minute and cooling it to within 5° F. of the wet bulb temperature with a wind velocity of five miles per hour. Water cooled in this louvre tower is handled somewhat differently from the usual methods in most plants. While the water is moved through centrifugal pumps, the power insted of being steam or electricity, is furnished by internal combustion gas engines.

Three of these engines are set in a small pump house placed near the cooling tower basin, the largest of which has a bore and stroke of 5⅛ inches and 6¼ inches, respectively. It is connected to a centrifugal pump delivering 1100 gallons of water per minute from the basin to the top of the tower and through the distributing pipes. The drive from the engine to the pump is through multiple V-belt. The other two engines are smaller, having L head construction with a bore and stroke of 4⅛ inches and 5¼ inches, respectively. These engines drive six-inch centrifugal pumps through V-belts.

All of the engines are equipped with air cleaners and oil filters. Ignition is by high tension magneto. Fuel is regulated through a common instrument, distributed to each of the engines through suitable piping. The exhaust is carried out through the roof of the building through flexible metallic hose and piping. These engines have been in service for a little more than a year without any difficulty being experienced in the service rendered. Compared to steam, charged for at the regular rate of gasoline plants, these engines, it is said, can be written from the capital investment within a few months.

To compensate for belt stretch, the engines were mounted on sliding bases, controlled through tension bolts. No stand-by pumps were placed in the plant, either steam or electric driven, and they must deliver a constant stream of water over the cooling tower at all times. Each engine is equipped with self-starters.

The steam generating unit in the plant consists of

three 250-horsepower marine type water tube boilers set on high fire boxes. Firing is through gas burners and fuel control valves. The boilers have been in service consistently over the operating period of the plant at about 110 percent of their normal rating, and have not been down for repairs.

Water for boiler feed purposes is softened in a zeolite unit to approximately 2½ grains hardness to give a thin film of scale to the tubes to prevent undue pitting. When a boiler is down, all that has been done to it is washing out the drums and tubes. So far, with this type of water and under the service required of them, it has not been found necessary to turbine the tubes to remove scale. Feed water is prepared through a feed water heater, and all of the steam that can normally be condensed is saved and returned to the make-up tank.

The plant was not constructed with sufficient size to process all the available gas during the flush production period of the new wells, and a part of it is taken care of through the older No. 1 plant, and that not handled there is "farmed" out to other gasoline manufacturers in the vicinity so that when the volumn drops to the capacity of the present plant, it may handle all that coming from the wells upon which the company has contracts.

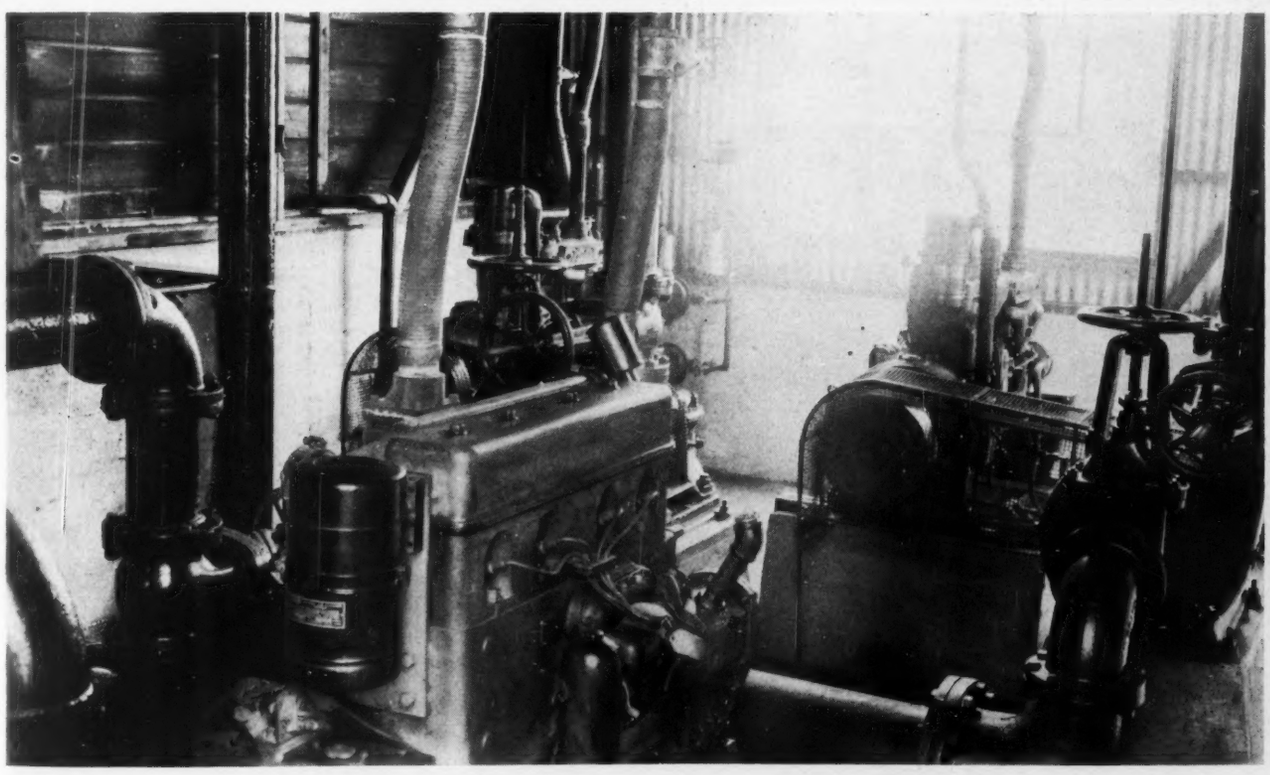
## LIQUEFIED GASES

Butane-propane mixtures, or simply butane, as it is called on the West Coast, is also being manufactured in the Huntington Beach field by O. C. Field Gasoline Corporation. The use of this product is growing steadily in California, and more than 1000 trucks and buses are using butane as a major fuel. Practically all of these units, with the exception of passenger buses operated in the cities, are heavy duty trucks hauling the maximum loads permissible over long distances at relatively high speeds. Because butane as a fuel in these internal combustion engines does not contribute to crankcase dilution, and because of the high octane value of the varying mixtures of butane and propane, exceptional mileage has been placed on individual motors before it has become necessary to overhaul them.

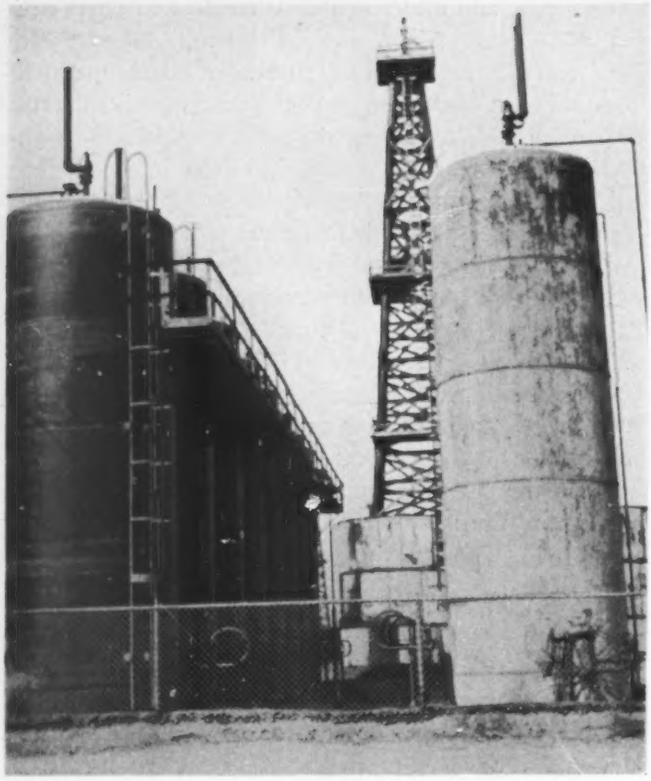
The natural gasoline from which the butane-propane mixtures are taken is manufactured in two plants operated by the company, but is fractionated in two columns located at plant No. 1. The production averages approximately 70,000 gallons daily having the following composition, raw:

| Composition | Percent by volume |
|---|---|
| Methane | 0.20 |
| Ethane | 0.41 |
| Propane | 5.46 |
| Iso-butane | 4.31 |
| N-butane | 22.39 |
| Pentane and heavier | 67.23 |
| Total | 100.00 |
| A. P. I. gravity | 85° |
| I. B. P. | 66° F. |
| E. P. | 250° F. |
| Recovery | 84% |

This material is processed to remove the necessary lower boiling fractions, in a 30-plate rectifying column, 42 inches in diameter by 54 feet in height. The hourly rate of charge to this column is approximately 3000



***Gas engines driving water circulating pumps in cooling system***



*New Type Vertical Pressure Storage Tanks*

gallons. Pumped to the column through exchangers and preheaters, it is processed under a pressure of 185 pounds, gauge, with a kettle temperature of 275° F. The top of this column is held at a temperature of 130° F. by refluxing with condensed overhead vapors. Approximately 99 percent of the condensible fractions are reduced to a liquid with 80° F. water contacting the atmospheric units in the louvre tower.

Bottoms from the primary rectifyer are as follows:

| Composition | Percent by volume |
|---|---|
| Iso-butane | 4.74 |
| N-butane | 24.70 |
| Pentane and heavier | 70.56 |
| Total | 100.00 |
| Vapor pressure (lbs. Reid) | 22 |
| A. P. I. gravity | 80° |
| I. B. P. | 78° F. |
| E. P. | 252° F. |
| Recovery | 96% |

The lower boiling fractions removed as an overhead stream are those from which the propane-butane mixtures are manufactured. This stream has the following composition.

| Composition | Percent by volume | G.P.M. |
|---|---|---|
| Methane | 2.13 | |
| Ethane | 5.32 | |
| Propane | 70.14 | 19.15 |
| Iso-butane | 16.32 | 5.30 |
| N-butane | 6.09 | 1.91 |
| Pentane and heavier | 0.00 | 0.00 |
| Total | 100.00 | |

This condensate is pumped back over the primary column to maintain the proper overhead condition with a ratio of 5½ to one.

It is also charged to the secondary fractionating column as the feed from which the propane-butane motor fuel is manufactured. Either one of two products are produced, depending upon the demand. One product is a 20/80 propane-butane mixture, and the other is a 30/70. Some of the truck and bus operators prefer a mixture contaning 30 percent of propane, while others use the heavier fuel.

The secondary column is operated at two pressures. That of 240 pounds, gauge, while a 20/80 butane-propane mixture is being prepared, and at 250 pounds, gauge, while the 30/70 mixture is being cut from the charge. The temperature in the kettle is maintained at 165° F. and the top of the column at 104° F. Overhead vapors from this column are led to boilers for fuel. The charge, when a 30/70 product is being manufactured, is introduced into the column above the seventeenth plate, but if a 20/80 product is desired, it is fed to the column on the fifteenth plate. Special high pressure liquid storage tanks have been erected in which to store the finished product.

## GASOLINE STORAGE

The company has erected a new battery of storage tanks in which the finished gasoline is placed after stabilizing to the desired grade. The original vessels placed in service were rendered unsafe for gasoline storage from a fire caused by burning crude nearby in the summer of 1934.

This battery of tanks were equipped with safety valves placed on connections in the upper head and set to open at a predetermined pressure. Equalization lines were connected from each tank to a common header so that when the volume of gas exceeds the capacity of any one safety valve, the equalization line permitted this excess to escape from one of the other safety valves on another tank. Because of these safety valves, none of the tanks passing through the fire were ruptured, but remained intact with the bulk of the gasoline remaining.

After the fire, preparations were begun leading to the erection of a new battery of storage vessels. The new tanks were fabricated with all seams, head, longitudinal and others welded. All connections where gauge glass fittings were to be installed, as well as charging and pumping out nipples were welded to the tank sheets. A short skirt upon which the tank seats were welded to the tank body so the assembly is a complete unit, ready to be erected when delivered at the plant.

The new battery contains eight tanks, each of which are 10 feet in diameter and 29 feet in height. The material from which they were constructed is 9/16-inch plates for the shells, ⅝-inch bottoms and ½-inch top heads. After completion, they were tested to 75 pounds cold water pressure to provide a safety factor of 4. The charging line connections were placed near the bottom head on the front, but the pumping out lines were placed on the side. The pumping out line is fitted with a welded turn, but the charging line is fitted with

a four-bolt flange. Control gates were placed at a convenient point. All of them are three-inch interchangeable from one point to another.

Instead of placing the water drains in the heads, or bottoms of the tanks, fittings were installed so that a small line could be inserted with its inside tip resting on the lowest part of the lower head. This line was made with a diagonal cut so that when it was placed in position, liquid drained from the tank came from the lowest part on the tank and all water can be removed without disturbing the gasoline.

Sample cocks were placed on each tank, with the line through which the gasoline is removed extending into the tank so it reaches approximately the center. It is located about two feet from the lower head seam and samples are taken in a bomb. Two thermometer wells were placed in each tank, one of which is about 10 feet, and the other about 20 feet from the base. Gauge cocks and glasses were placed in the usual manner on the side of the tank at the front. The gauge poles were fitted with steel tapes instead of the usual marks on the wood.

In addition to individual steel ladders fastened permanently to the side of each tank, an all-steel walk was placed across the entire battery near the top. Each ladder is fitted with safety baskets to prevent accidents to the employes if one should slip when ascending or descending a ladder. These ladders are all placed beside the gauge glass column for the convenience of those inspecting the tanks or contents.

Pipe bends were used in the charging lines to provide flexibility in this connection so that any vibration will not place an undue strain on the lines. The tanks were all erected in a vertical position, leveled by gouting under the flange skirts upon which the tanks seat. A continuous foundation was poured for the eight tanks in an excavation so that the earth would form a firm bearing in the hard subsoil.

Each tank was fitted with a four-inch connection welded in the center of the upper head. The short stub nipple used for this purpose has a companion flange welded to it so a reducing tee could be placed in position on it. This is a standard four-inch by two-inch reducing tee upon which a four-inch safety valve was bolted. Each safety valve is set at 20 pounds operating pressure and the escaping vapors can pass through the side of the valve through a short nipple, an ell, and a riser. The side outlet from the reducing tee is for the purpose of connecting the equalizer line which extends downward from this point to a buried header near the foundation of the tank battery.

Insurance inspectors as well as those connected with other gasoline manufacturers, after a minute and thorough inspection of the tank assembly expressed their approval of the methods of connecting the charging and pumping out lines, gauging facilities, safety features embodied in the ladders and all steel overhead walks. They were especially interested in the manner by which the tanks were provided with safety valves and equalizer lines to provide a rapid escape of vapors generated if heat should be applied to the outer surface of the tanks.

***Details of piping hook-up on new gasoline storage tank battery***

# The Structure of Liquids and the Mechanism of Viscosity

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***Before American Petroleum Institute, Dallas, November, 1934***

AN adequate appreciation of the properties of liquids can be based only upon a clear picture of the structure of the liquid state and the character of the forces which operate in maintaining it. It will certainly be agreed that most technical men are hazy in their concept in this field and the first purpose of this article is, not to present a new analysis or new ideas but to attempt to develop clarity in the qualitative understanding of the situation. It is hoped that this clearer insight will lead to an explanation of the general relationships of the properties of liquids, particularly of the one in which we are mainly interested, namely, viscosity.

The kinetic theory of gases gives a satisfying and convincing explanation of the properties of the gaseous state. It visualizes rapidly moving molecules (particles) traveling in random directions and at variable speeds, whose average kinetic energy of translation depends only on the temperature and is independent of the size or structure of the particle. The pressure exerted by the gas, i.e., its tendency to expand, is caused by the bombardment of these particles against the walls of the containing vessel, and is therefore proportional to the concentration of the particles and inversely proportional to the volume occupied by any given quantity of the gas. In a liquid the molecules are obviously closely packed together. Furthermore, the kinetic theory indicates that their effective average kinetic energy of translation is identical with that of a gas at the same temperature[1] Hence it is necessary to explain the fact that the molecules, despite their close packing and high kinetic energy, do not exert a high pressure upon their surroundings. The explanation universally accepted is that molecules attract each other, because of forces which become very large in magnitude when the molecules are close together, but decrease rapidly to a completely negligible value when they are far apart. To understand the behavior of liquids it is imperative to have the clearest possible picture of the character of these attractive forces between the molecules.

## INTERMOLECULAR ATTRACTIONS

There is no doubt that both molecule and atom are electrical in structure, but while electrically neutral as a whole, the charges of opposite sign which exist within them are not coincident in position, so that in consequence there exist around the molecules stray fields of electric force. The nature of these fields of force, so far as influence upon the structure of the liquid state is concerned, is probably best visualized by analogy to magnetic fields. Thus, a short bar magnet, while surrounded in its immediate neighborhood by a strong, effective magnetic field, will exert no appreciable magnetic effect at a distance from itself great in comparison to the distance between its poles. If, now, beside this first maget be placed a second, equal in length and magnetic strength, but with poles reversed, the pair will in large degree neutralize each other. Thus, the distance at which the magnetic effect of the combination becomes negligible is far smaller than the corresponding distance for the first magnet. None the less, around the pair there still exists a residual stray field of magnetic force capable of exerting considerable magnetic attractions and repulsions upon magnetic bodies coming within its range of action. There is every reason to believe that around the molecules exist analogous stray fields of electric force, that are appreciable no matter how complete the internal neutralization of the structure, as for example in the case of the noble gases.

This concept of the fields of force around the molecule leads to three conclusions which offer explanations of facts otherwise difficult to understand. In the first place, the range of action of the forces is extraordinarily small, but their magnitude may be enormous within that range. In the second place, the forces are clearly effective only on the surface of the molecule or in its immediate neighborhood, and in this sense the total force per molecule should be proportional, other things equal, to the surface of the molecule and hence in general increase with the molecular weight. In the third place, there is every reason to anticipate wide variation in the intensity of the forces with variation in the structure of the molecule, depending on the character of the elements involved and the nature of their arrangement in the molecule.

The molecules of a fluid are subject to the action of two sets of forces, one group tending to separate them and expand the fluid, the other to draw the molecules together and compress it. The actual state of the fluid

[1]This conclusion is confirmed by the fact that, at least in dilute solutions, osmotic pressure follows the gas laws. Each molecule of the solute can be looked upon as a tell-tale, indicating the average kinetic energy of translation of all molecules in the liquid, including those of solvent.

is determined by the balance of these disgregating and aggregating forces. In the case of a gas, the major disgregating force is the repulsive effect of the molecules caused by their kinetic impacts with each other; the major aggregating force is the externally applied pressure, usually exerted by the walls of the containing vessel.[2] In the case of a liquid, the disgregating tendency is probably still due largely to thermal molecular impacts, but, owing to the propinquity of the molecules, their mutual attractions have become the predominating aggregating force to a degree almost completely overshadowing the effect of the externally applied pressure.

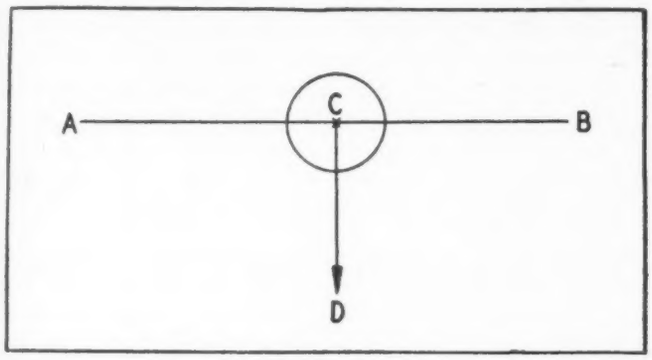



**FIGURE 1**

***Diagram of a liquid-gaseous interface showing the sphere of action of a molecule at C and the resultant of all liquid molecular forces in the sphere acting on the molecule***

The effect of the mutual molecular attractions is substantially equivalent to a hypothetical externally applied pressure, as can be seen in Figure 1. The line AB represents the interface between a liquid and its vapor. C is a molecule in that interface, the circle around which represents its sphere of action, i.e., the zone within which its attraction for other molecules is appreciable. In the liquid half of this sphere of action lie a large number of molecules, each of which is attracting C with a force, whose sidewise component is neutralized by the effect of a corresponding molecule on the other side of a plane through C perpendicular to AB, but the inwardly directed component of which is cumulative, the total effect being represented by the arrow CD. Because of the small number of molecules in the vapor side of the sphere of action, the corresponding outwardly directed force may be neglected. Since every molecule in the surface layer AB is attracted inwardly in this fashion, it is clear that the resulting effect is equivalent to an inwardly directed pressure upon the surface of the liquid. This pressure is the so-called interior pressure of liquid. While no exact method of measuring it has ever been developed, its value can be approximated in various ways. For ordinary organic liquids, it usually amounts to from 500 to 3000 atmospheres, but for some liquids, e.g., water, it may be as high as 12,000 to 15,000 atmospheres. It will be noted that these pressures are enormous in comparison with the ordinary vapor pressures of liquids. As the critical condition is approached, the two become more nearly equal. In any event the state of the liquid is determined by the balance between the sum of the internal and external pressures on the one hand and the expansive effect of the intermolecular kinetic impacts on the other.

The disgregating effect of the kinetic impacts is determined by the average kinetic energy of the molecules, and this in turn is, approximately at least, independent of molecular weight, structure and propinquity, and proportional to the absolute temperature. Consequently, so far as the disgregating effect is concerned, changes in temperature should produce the same result for all liquids at all temperature levels. However, the characteristics of the aggregating force of internal molecular attractions are entirely different. The magnitude of the force increases greatly with the molecular weight, i.e., with the size of the molecule and its surface, and also with molecular propinquity, or, what is equivalent to the same thing, liquid density.

## MECHANISM OF VAPORIZATION

It is obvious that the tendency of the molecule to escape from the liquid into the vapor will increase with the temperature, because of the increase in its average kinetic energy of translation. It is equally obvious that its net tendency to escape (i.e., its vapor pressure) will be the less the greater the attraction of the liquid for it. This backward attraction toward the liquid surface will increase with the molecular weight and the density of the liquid, and with the intensity of the surface forces. Furthermore, because of the rapid increase of the attractive forces as the distance between the molecules decreases, the effect of changing liquid density will greatly outweigh the effect of changes in molecular weight. Furthermore, the evidence indicates that the same is true with respect to the change in intensity of the surface forces, i.e., of the so-called polarity of the molecule.

The results of these varying effects is well illustrated in the influence of temperature on the vapor pressure of a liquid. An increase in temperature produces a relatively small increase in kinetic energy of the molecules, with a correspondingly small increase in gross escaping tendency. If the character of the liquid itself remained unchanged, the increase in vapor pressure would be slight. However, because of the increase in kinetic energy of the molecules in the liquid, their tendency to separate increases, and the separation itself decreases the mutual molecular attractions in the liquid out of all proportion to the increase in the separating tendency as such, so that there is a great decrease in the net molecular attractions. In consequence, because of the relatively minor increase in gross tendency of the surface molecule to escape from the liquid, together with the major decrease in the forces pulling it back into the liquid caused by the drop in liquid density, the net increase in escaping tendency, i.e., in vapor pres-

[2] In the case of the atmosphere the aggregating effect is the force of gravity.

sure, is greatly out of all proportion to the rise in temperature which caused the change. In other words, the vapor pressure curve changes extremely rapidly with temperature—a property universal in all normal liquids.

### SURFACE MOLECULE C

Referring back to the preceding diagram, visualize what is happening to the surface molecule, C. It is bumping around at a high but variable velocity, colliding with the molecules in its neighborhood and rebounding from them. At some instant it will undergo a collision such that its rebound gives it a component of velocity perpendicular to the surface of the liquid, out towards the vapor space. If its velocity in this direction is small, it will soon be stopped by its attraction backward toward the liquid surface, and, like a ball thrown into the air, it will fall back again into the liquid. The greater its component of velocity outward, the higher it will rise from the liquid surface before returning. If its outward component of velocity is sufficient, it will rise above the liquid distance greater than its sphere of action, and in this event it will lose all tendency to return to the liquid. In other words, this particular molecule will have evaporated, i.e., transferred itself permanently from the liquid into the vapor state. Clearly, in this transformation, the molecule absorbed from its neighboring molecules in the liquid the energy requisite for overcoming the attractions of the liquid for it—in other words, furnished its energy, i.e., its heat of vaporization.

A second illustration is the influence of molecular weight on boiling point. Consider, for example, the straight chain paraffin hydrocarbons. From our knowledge of their chemical structure, there is no reason to anticipate marked variation of intensity of the surface forces from one of these hydrocarbons to another. Therefore, the total attractions ought to be roughly proportional to the total surface, which, however, in this group of substances would be approximately proportional to the molecular weight. Consequently, the attractive forces should increase with molecular weight, whereas the disgregating tendencies, due to kinetic energy, should be independent of it. Consequently, it should be more difficult to separate from the liquid the molecules of a compound of high molecular weight than those of one lower in the series. Since the only way to increase the disgregating tendency is to increase the temperature, it should require higher temperature to transform high-molecular weight liquids into vapor—in other words, boiling point should increase with molecular weight, as is of course well known to be the case. Indeed, no compounds of really high molecular weight are low boiling.

The outstanding differences between the viscosity characteristics of gases and liquids are three: the viscosity of a gas is always small, whereas that of the liquid is relatively high; changes in density of the gas have practically no effect on its viscosity, whereas the influence of the density of the liquid on its viscosity is very great; finally, the viscosity of a gas increases with temperature, whereas that of the liquid decreases. Why these characteristics, and particularly why these differences between the two types of fluids?

Visualize a gas flowing in streamline motion. Each element or lamina of the gas is moving in a smooth, streamline curve, slipping past a neighboring parallel element moving at a lower velocity. The molecules in both elements are moving in the disordered motion of thermal translation, but superimposed upon this is the directed motion of fluid flow. However, the latter is larger in the rapidly moving element than in the neighboring slower moving one. Owing to the thermal agitation, molecules are continually passing from one element to the other. As a molecule moves from the zone of high velocity into that of low, it collides with the molecules of the latter, and is obviously slowed down. While a part of its former directed energy is imparted to increasing that of the molecules of the slower moving element, a part is dissipated as undirected energy, not only of molecular translation but also usually of one form or another of molecular vibration. Similarly, slow moving molecules wandering into the high velocity stream slow down the latter and, while themselves speeded up, there results a net dissipation of directed into undirected energy, i.e., a conversion of work into heat. This loss of directed energy is the friction of viscous flow.

Visualize doubling the density of the gas in such a case of streamline flow. Clearly, this results in doubling the number of molecular collisions, tending to increase energy degradation due to viscous friction. However, a given molecule would on the average travel only half as far between impacts. Consequently, the effective distance between neighboring elements is halved. This results in halving the velocity differences between the elements and consequently halving the energy dissipation per impact. Clearly the effects tend to cancel qualitatively, and analysis of the mechanism of energy loss on the basis of the kinetic theory shows that the cancellation is quantitative. This means that the energy degradation is unaffected by changes in gas density, i.e., the viscosity of the gas is independent of the density and hence of the absolute pressure, so long as deviations from the gas laws are negligible. Similarly, increase in temperature of the gas increases the thermal agitation of the molecules, thus increasing the frequency of collision and of transference of molecules from one element to another, resulting in increased energy dissipation, i.e., in increased viscosity of the gas.

If now one considers streamline flow in a liquid, it is clear that every factor just discussed with regard to the viscosity behavior of a gas is equally applicable in the case of the liquid. Why, then, does increasing density so enormously increase the viscosity of the liquid, whereas it has no effect on that of the gas, why is the viscosity of the liquid so much higher than that

of the gas, and why is the effect of temperature exactly the opposite?

## MECHANISM OF LIQUID VISCOSITY

The answer is found in the influence of the mutual attractions of the molecules. In a gas the average intermolecular distance is so great that the effect of these attractions is negligible, whereas in the liquid they preponderate. Because of the thermal agitation of the molecules in a fluid it is extraordinarily difficult to picture the condition diagrammatically, but an attempt has

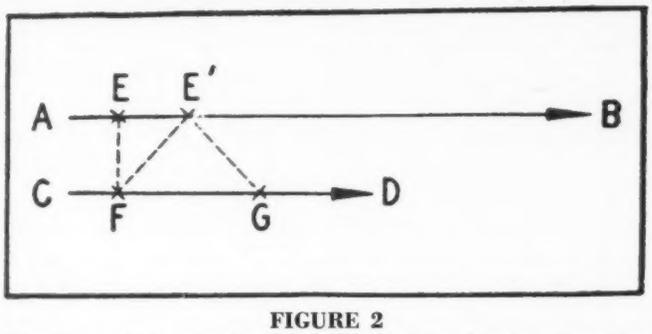



**FIGURE 2**
***Diagram of the mechanics of the intermolecular attraction in streamline liquid flow***

been made in Figure 2. Consider AB and CD as parallel elements of flow in a liquid, the relative velocities of which are indicated by the length of the arrows. E is a single molecule in the stream AB, and F and G are the two neighboring molecules in the adjoining element of flow. Now visualize E as moving into the position E′ relative to F and G. Because of the proximity of the molecules, there is a large attractive force between E and F, and clearly energy must be expended in separating these two molecules against this attraction as E moves into the position E′. Furthermore, this expenditure is directed energy, i.e., work. However, as soon as the position E′ is passed, the net attraction of E′ is toward G rather than toward F, so that further forward movement from the position E′ involves recovery of an amount of energy exactly equal to that just expended. However, E′, instead of continuing to move in the direction AB, will be drawn toward G by a large and progressively increasing force, will collide with it, and rebound from it. Furthermore, the rebound is sure to be in some degree randomly directed, so that the corresponding energy recovered due to the attraction of E′ by G will be randomly directed, i.e., will be in the form of heat. In other words, the work of separation of E and F due to the flow will involve conversion of directed into undirected energy, i.e., degradation of work into heat. The magnitude of this loss will depend on the magnitude of the mutual attractions: in the case of the gas the intermolecular distances will be so great that this particular loss will be negligible;[3] in a liquid it will be great, and obviously it will be greater the closer the molecules, i.e., the greater the density of the liquid.

[3]In the gas the molecules attract just before and after collision, but not to a significant degree in their mean positions, and hence not at the time that directed energy is being imparted to them.

The underlying reasons for the differences in the viscosity characteristics of gases and liquids now become clear. The viscosity of the liquid is far greater than that of the gas because in the latter the energy degenerated by molecular attractions is negligible while in the former it is preponderant. The viscosity of the liquid decreases with temperature because expansion greatly reduces the intermolecular attractions and hence the friction losses they induce. Increase in liquid density at constant temperature brings the molecules closer together, results in large increments in the attractive forces and corresponding increases in viscosity. Rise in temperature at constant volume leaves the total attractive forces substantially unchanged but decreases their net effect because of the increase of the repulsive tendencies due to the translational velocities of the molecules. Even more striking is the insight given into the temperature coefficient of viscosity. The kinetic theory indicates that the effective translational kinetic energy of the molecule is proportional to the absolute temperature, the constant of proportionality independent of molecular size and structure. However, the actual degree of separation of the molecules is determined by the balance between the disgregating effect of this translational energy on the one hand and the aggregating effects of external pressure and intermolecular attractions on the other. Clearly, if temperature be increased a given amount the molecular disgregating translational energy is increased a definite amount, which is independent of temperature level. Now liquid viscosity is a measure of the net effective intermolecular attractions. Hence, equal temperature increments should produce in liquids of equal net attractions, i.e., of equal viscosities, at least approximately equal viscosity decreases, irrespective of the temperature levels. This remarkable conclusion is strikingly confirmed by the data. A plot of, not $d\mu/dt$, but, because of the extreme range covered, $d\mu/\mu\, dt$, i.e., $d\ 1n\mu/dt$, the fractional change in viscosity with the temperature versus the viscosity for a large number of liquids, mainly organic but including water, on which data are available, shows deviations from a smooth curve rarely exceeding 20 percent, and averaging far less, particularly at high viscosities. That liquids so diverse in character, both chemically and physically, differing in viscosity as they do over 10,000 fold, should fall so nearly on a common curve is striking confirmation of the soundness of the analysis here presented. A graphical integration of the curve is shown in Figure 3, in which viscosity is plotted on a semilogarithmic scale against temperature difference. It signifies that viscosity as determined by change in temperature is independent of temperature level, i.e., that all viscosity temperature curves are symbatic. Hence, a knowledge of the viscosity at one temperature enables one to construct the whole viscosity temperature curve.

It is not implied that this relation is absolute. Thus mercury is completely abnormal in behavior relative to

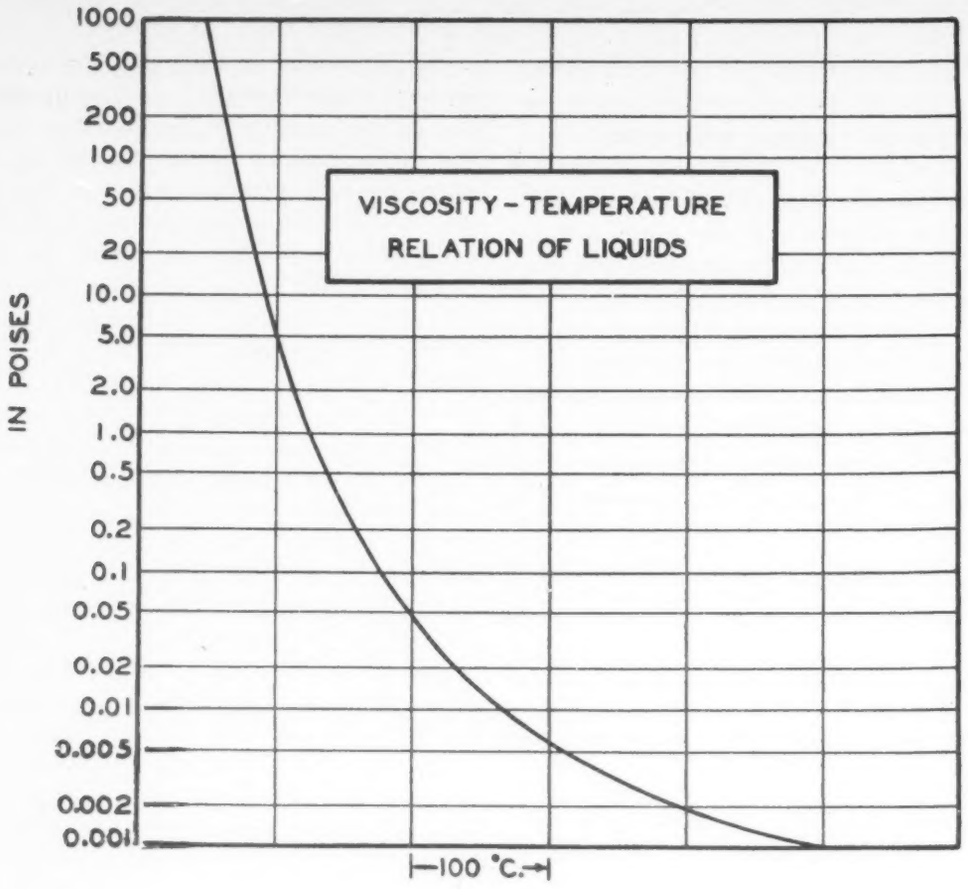



**FIGURE 3**

this curve. Furthermore, some pure organic liquids are anomalous. However, it can certainly be considered as a standard of normal behavior for pure organic liquids, and the causes of large deviations from it must be sought in some abnormality of character or structure.

## CHANGE IN VISCOSITY

Study of Figure 3 will emphasize the point that even the fractional change in viscosity with the temperature increases with viscosity itself. Hence the change in viscosity with temperature rapidly becomes abnormally high at high viscosity levels. On this basis it does not appear hopeful to seek pure viscous liquids of low viscosity-temperature coefficient.

From the point of view of the lubrication engineer, this analysis severely circumscribes the manipulating of the inter-relationships of the important physical properties of ordinary hydrocarbon lubricants. Because of the connection between molecular weight, volatility and viscosity, one can hope to find lubricants of low viscosity only among compounds of low molecular weight and high volatility, and vice versa. Even more serious is the limitation that the temperature coefficient of viscosity is determined predominantly by the viscosity itself, i.e., that liquids of high viscosity inevitably have rapid change of viscosity with the temperature. Expressed in the phraseology of the lubrication engineer, the curve of Figure 3 corresponds to liquids of roughly zero viscosity index. It is true that certain pure hydrocarbons exhibit decidedly lower temperature coefficients of viscosity than correspond to this figure, i.e., show higher viscosity indices. This is probably due to some type of molecular interlocking induced by the character of the molecular structure, but it seems likely that potential developments in finding lubricants of high viscosity level and low temperature coefficient of viscosity are limited. Fortunately, however, by fundamentally modifying the structure of the fluid lubricant it is possible profoundly to alter the relationships inherent in pure liquids and their relatively simple mixtures. However, in order to understand these relationships it will be necessary to discuss for a moment the characteristics of two types of fluid in which the lubrication engineer has no direct interest, namely, suspensions and emulsions.

## SUSPENSIONS AND EMULSIONS

Mathematical analysis shows that the viscosity of a dilute suspension of rigid, spherical particles, uniform in size is given by the Einstein equation:[4]

$$\mu = \mu_o\ (1 + 0.5v)/(1 - v)^2$$

in which $\mu_o$ is the viscosity of the liquid in which the particles are suspended, $\mu$ the viscosity of the suspensions, and v the volume fraction of the suspended particles. The viscosity of the suspension is, as the equation indicates, independent of the size of the particles and rate of shear. The relationship has been

[4]For low values of v this simplifies to the form frequently met, $\mu = \mu_o\ (1 + 2.5\ v)$.

carefully tested experimentally and is undoubtedly sound. Furthermore, the influence of variation in particle size in a given suspension is not great provided the fractional size distribution remains unchanged, and, while the equation breaks down at high values of v, it still remains true that at these high values the viscosity is a unique function of the volume fraction. There is no doubt that the high viscosity shown by ordinary suspensions is due solely to this Einstein effect, i.e., to the volumetric interference of the suspended particles with the movement of the liquid. Furthermore, the same is true of the viscosity of emulsions of one liquid in another; in other words, the interfering, suspended particles need not be rigid. The resistance to deformation of a small droplet caused by its surface tension is ample to give the effect.

It is clear that change in temperature of either a suspension or an emulsion will make so little change in the volume fraction, v, of the suspended particles that this factor can probably be neglected. If, now, keeping this in mind, one will differentiate the Einstein equation with respect to the temperature and divide the result by the original equation, one finds that the fractional change of viscosity of a suspension with the temperature is that of the solute in which the particles are suspended. However, as just pointed out, the viscosity of the suspension is greater, and in the case of concentrated suspensions far greater, than that of the solvent. Consequently, fluids of this type are characterized by having viscosity-temperature coefficients far lower than correspond to their viscosities. In other words, they do not lie on the curve of Figure 3 for pure liquids. In the phraseology of the lubrication engineer, they possess high viscosity indices. Unfortunately, however, fluids of this type are unsuited to lubricants.

## SOLUTIONS EXHIBITING THE VISCOSITY CHARACTERISTICS OF SUSPENSIONS AND EMULSIONS

A large class of materials are known, the so-called emulsoid colloids, which dissolve in suitable solvents without obvious chemical reaction to form solutions whose viscosity is high relative to the concentration of the solute. These solutions exhibit many of the viscosity characteristics of suspensions or emulsions, i.e., they behave as though the solute consisted of large, discrete particles floating in the liquid. However, when the viscosities of these solutions are compared with the values one would antiicpate from the Einstein equation, it is found that they are abnormally high. There is every reason to believe that this same volumetric interference of suspended particles is the fundamental cause of the high viscosity exhibited by so-called colloidal solutions of many materials of extremely high molecular weight, although in this case, as will appear later, other important factors enter into the phenomenon. Finally, it is important to recognize that while the shape of the suspended particles has but little effect so long as their dimensions are roughly the same in all directions, rod-like or chain-like particles produce viscosity increases in excess of the solvent out of all proportion greater in relation to the volumetric fraction of the particles. It has long been assumed that this high viscosity was due primarily to a swelling of the particles induced by some sort of combination of solute and solvent, by adsorption or otherwise, the so-called solvation, and it still seems likely that this is an important factor in many cases. However, in recent years Staudinger in Germany, supported by the results of many other workers, has offered convincing evidence that in many cases another factor is fundamentally important, if not indeed predominant. Staudinger has shown that solutions containing solutes of high molecular weight and extremely long, chain-like molecular structure exhibit the viscosity characteristic outlined above in high degree, even in cases in which there is little or no supporting evidence of solvation. Staudinger explains this fact by modifying the concept underlying the Einstein equation. That equation assumes that the high viscosity of a suspension of rigid, spherical particles in a liquid is due to the interference of the particles with the liquid flow, and it is not difficult to visualize that this interference would depend primarily on the volumetric fraction of the suspended particles. Staudinger points out that, if the suspended particles, instead of being spheres, are in fact long, rod-like bodies, in viscous flow, in which alone the phenomenon of viscosity exhibits itself, these rods are sure to turn and tumble in the moving fluid. Clearly, the tendency of the rods to interfere with each other, and therefore with the motion of the fluid, is far greater than the tendency of spheres of equal volume. Staudinger postulates that the effective interfering tendency is proportional, not to the volume of the rods, but to the volume of the cylinder of revolution generated by rotation of the rod about an axis through its center perpendicular to its length. Furthermore, in at least a qualitative way he and other workers in the field have been able to confirm the dependability of this assumption by measurement of the viscosity characteristics of solutions of chain compounds of the type in question, synthesized by dependable methods and of accurately known molecular weights. Staudinger's formula leads to the conclusion that the viscosity of a solution of this type is a function not only of the volumetric fraction of solute, v, but also of the molecular weight, increasing rapidly with the latter. However, exactly as in the case of suspensions, this leads to the conclusion that the temperature coefficient of viscosity of the solution is that of the solvent, since the molecular weight changes even less with the temperature than the volume fraction of solute. In other words, defining Staudinger viscosity as the unduly high viscosity imparted to a solution by an emulsoidal solute of high molecular weight and chain-like structure, Staudinger viscosity gives to the lubricating engineer the possibility of attaining the high viscosities characteristic of pure compounds of extremely high molecular weight, combined with the low temperature coefficients of viscosity inherent, in the case of pure

substances, only in those of low viscosity and low molecular weight.

The possibilities just outlined open a new field of development for the lubrication engineer, but its characteristics must be exploited on the basis of experience. However, one can point out certain pitfalls to be avoided. In the first place, it is obvious that the solutes employed must be adequately stable under conditions of practical use. In the second place, they must be soluble in the low-viscosity diluents available, and these in turn must be suitable in stability, volatility, and other characteristics. Most important of all, however, in the synthesis of the thickening agents one must secure a proper balance in molecular weight.

From the point of view of securing a maximum viscosity increase with a minimum of addition agent, one would prefer a solute of maximum molecular weight. However, the interference of such solute molecules with each other in solution becomes excessive and they tend to develop a structure, perhaps best described by the phrase "brush heap." The formation of this structure is the cause of the phenomenon of gelation. When it develops, the liquid no longer has a constant viscosity, but its viscosity changes rapidly with rate of shear, even at low rates of distortion. Indeed, it requires a finite force to produce even differential rate of flow. In other words, the solution has taken on the properties of plasticity, and is no longer a liquid in the strict sense of the term. In general, such a liquid possesses a specific gelation temperature, above which it will not develop a gel structure; but, unfortunately, even at temperatures distinctly above the gel point the tendency toward structure formation is evidenced in a rapid rise in viscosity as temperature falls. Indeed, the viscosity-temperature curve of such liquids extrapolates to infinite viscosity at the gel temperature. This is most easily seen by plotting, not viscosity, but its reciprocal, fluidity, which frequently is practically linear with the temperature, extrapolating to zero value at the gel point. This means that the Einstein equation in the sense defined above, even as modified by Staudinger, breaks down as the temperature of gelation is approached. Hence, emulsoidal solutions of this type, instead of having temperature coefficients lower than those of pure liquid of the same viscosity, have in the neighborhood of the gel point coefficients which are far higher, i.e., rather than exhibiting high viscosity indices they show negative values which may become very large. Consequently, while to get a marked Staudinger viscosity effect it is necessary to have molecular chains of high molecular weight, it is equally essential to avoid excessive values.

## SUMMARY

The modern physical concept of the structure of the molecule, leading as it does to the assumption of the existence of powerful attractive forces in the immediate neighborhood of the molecular surface, makes it possible to get a far clearer picture than hitherto of the mechanism of liquefaction. This leads to qualitative explanation of the influence of molecular weight and molecular structure on volatility and boiling point, on liquid density and viscosity. It gives a clear picture of the reasons for the differences in viscosity behavior between liquids and gases, particularly the influences of temperature and pressure. It leads to the unexpected conclusion that for pure liquids the temperature coefficient of viscosity is determined predominantly by the viscosity itself, always resulting in extremely high temperature coefficients for viscous liquids. However, modern knowledge of the properties of what may be described as nonhomogeneous liquids, consisting of mixtures of large, chain-like molecules with ordinary liquids, makes it possible to prepare liquids of abnormally low viscosity-temperature coefficients relative to their viscosities. Mixtures of this type hold promise of developing extreme importance in the field of lubrication, particularly of hydrocarbon lubricants.

# *Outlook for the Automotive*
# High-Speed Diesel Engine
## *in Heavy-Duty Transport*

**JOSEPH GESCHELIN**
***Engineering Editor, Automotive Industries***

**THE paper offers an appraisal of the future of the automotive Diesel, in a discussion stripped of the fallacies that have grown up around this important development.**

**It is shown that the present market for the Diesel comprises a good slice of the current registration of some 161,000 trucks of 2½ tons and up in capacity; as well as some proportion of the yearly production of about 20,000 vehicles in the same category.**

**Acceptance of the Diesel is based almost exclusively on fuel economy, which under present conditions is of the order of 60 to 80 percent of the gasoline bill. Ultimately, if and when the price of fuel oil approaches the price of gasoline, the Diesel must rest on its inherent economy of the order of 30 to 50 percent saving in fuel cost.**

**It is quite evident that the entire development depends upon the fuel situation—availability of acceptable Diesel fuel, future course of fuel price, probable effect of taxation. For this reason the author recommends immediate action on the development of minimum Diesel fuel specifications, reasonable control of fuel price, vigilant study of tax situation, closer cooperation between petroleum industry and Diesel engine designers.**

**This paper was presented at the Fifteenth Annual Meeting, American Petroleum Institute, at Dallas, Texas.**

WHAT of the market for the high-speed automotive Diesel engine? What is its significance to the petroleum industry at large?

While it would be most difficult to answer these questions directly and without reservation, this much is certain: that of the power units in the enginering world, the high-speed automotive Diesel engine is most dependent upon its fuel. Not only performance which, obviously, is a direct function of the characteristics of available fuels, but the whole economic future is linked with the availability of its fuel as well as the ultimate trend in fuel cost. The future, therefore, resides to a large extent in the attitude of the petroleum industry.

Specifically, the purpose of this paper is to take up objectively the following considerations which have a direct bearing on automotive-Diesel development in this country:

1. Status of the automotive Diesel engine.
2. Analysis of its present market.
3. Some forecast as to the potential market.
4. Study of the economic factors involved.

Without delving too deeply into past history, it is apparent that while the impetus given to the Diesel has come from many sources, unquestionably the biggest factor has been the adoption of Diesel power by truck and bus operators all over Europe. Few have stopped to reason that an entirely foreign set of economic conditions was responsible for the European development, particularly excessive taxation and high gasoline prices.

Came the well-meaning but misinformed friends of the Diesel engine in this country. Probably all of you remember how several years ago a widely syndicated newspaper columnist told his wondering audience of a new era in transportation with a wonderful power plant that would use fuel just as it came from the ground. One could almost picture large trucks backing up to a hole in the ground and fueling from a pool of crude oil. Then came claims of remarkable performance and seemingly magical economy. To this end comparisons were made using as a basis the wholesale price of fuel oil against station price for gasoline, with no thought whatever to the possibility of a tax on the fuel oil.

As the movement slowly gained momentum, we began to hear from the alarmists. They spoke of the dire calamity arising from a fuel shortage, the possibility of fuel oil prices sky-rocketing to the point where the Diesel fuel would cost much more than gasoline. And, only a few weeks ago we printed in *Automotive Industries* an abstract of a paper published in one of your own petroleum journals in which the author warned Diesel engineers that the fuels that burn most satisfactorily in high-speed engines are likely to be scarce and expensive.

Let me say at this point that no one need become alarmed at the prospect of a great demand for Diesel fuel. In fact, it is really amazing to learn from the statistics given in a later section of this paper that of all the motor vehicles registered in this country, scarcely one percent could be customers for the Diesel at the present time. Is it reasonable to conclude that this small select group could burn enough fuel oil to upset a market serving nearly 24,000,000 vehicles?

In spite of these smoke screens, the automotive Diesel has gained a sound and firm footing in many important quarters. Let us, therefore, look clearly down the

middle course, and attempt a perspective of this important development.

It is safe to say the automotive Diesel has inherent advantages in fuel economy that must appeal to operators of certain kinds of equipment. And, for the moment, the Diesel engine enjoys an unparalleled advantage due to a combination of circumstances—an abundant, cheap fuel, not yet penalized by the imposition of a special tax. The next point is that a number of great groups of users in this country are sold on the Diesel engine. These include large truckers, operators of industrial equipment, and the users of farm tractors. These people have been thoroughly convinced by demonstrated economy, and it is reasonable to assume that they will continue to constitute the primary market for the Diesel engine.

Finally, whatever momentum there may be in this direction is greatly intensified by the entry of important engine builders and the acceptance of their product, at least optionally, by the manufacturers of motor trucks, tractors, and industrial units.

With this preliminary introduction, let us look into the development from a purely objective viewpoint.

## WHY THE DIESEL ENGINE?

For a quick picture of inherent economy see Figure 1.

Analysis of published records of fuel economy coming from operators all over the world, and including the experience in this country, indicates that the Diesel is cutting fuel costs between 60 and 80 percent—the variation being due to the differences in cost of fuel in various localities. Naturally, this extraordinary economy is due to the present low fuel cost as well as the absence of a special fuel tax; it may not last forever, but certainly it is present and may continue for some time to come.

Unquestionably, fuel economy is the chief reason for

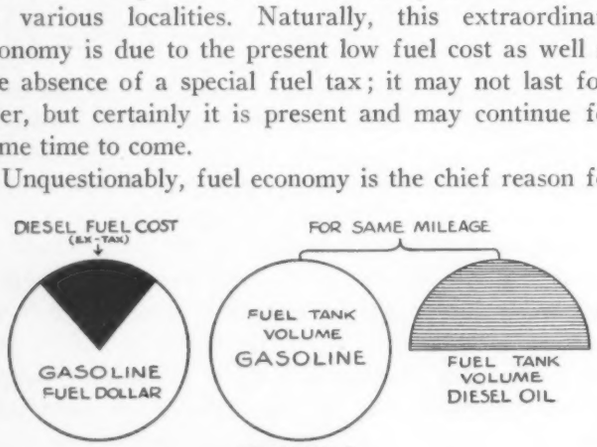



**FIGURE 1**

***Diesel and Gasoline Economy Compared on Basis of Present Operating Figures and Intrinsic Economy***

using the Diesel, and the one which appeals most to the operator. And, ultimately, this economy should be reckoned in terms of the inherent efficiency of the Diesel. Theoretically, the Diesel cycle exceeds the thermal efficiency of the Otto cycle by about 25 percent; actually, the operating experience all over the world proves that Diesel-equipped vehicles are giving almost twice as much mileage per gallon of fuel, the intrinsic economy on the basis of fuel tank volume running about 30 to 50 percent in favor of the Diesel. A reasonable explanation for this is that the Diesel engine has a much flatter fuel consumption curve than the gasoline engine; and, since many vehicles are operated at part throttle for a great deal of the time, the over-all economy is almost twice as high as the theoretical thermal efficiency may indicate.

More specifically, the operators of heavy-duty equipment, as exemplified by fully-loaded truck-tractor trains, actually show a saving of 3 to 5 cents per mile on their fuel, tax-free.

Another decided advantage, and one which has not been stressed to any extent, is the fact the Diesel power plant runs much cooler, at lower radiator temperatures, due to more efficient burning of the fuel and, consequently, less rejection of waste heat to the water jackets. This is particularly advantageous on tractor and industrial equipment; as it makes possible the use of smaller, lighter, cooling systems, and eliminates the troubles due to over-heating when operating under full-load conditions in a hot atmosphere or in places where the direct entry of atmospheric air is blocked. It has also proved to be a vital factor in truck operations on the Pacific Coast on runs through the torrid Imperial Valley and over the high ranges of the Rockies.

Still another factor of outstanding importance lies in the demand of our export market. In the past the automotive industry has exported an average of almost 25 percent of its yearly truck production, which rose to 40 percent in 1929, according to figures published in the 1934 statistical issue of *Automotive Industries*. With the growing demand for Diesel power in foreign countries, particularly South America, there is grave danger of losing this great market unless American truck manufacturers are in a position to supply Diesel equipment wherever it is specified. With the advent of the production of Diesel engines in this country, our truck manufacturers have been placed in a position to compete on better terms with the European manufacturers— who have been making inroads on our export business. The same is true of domestic tractor manufacturers.

## SCOPE OF APPLICATION

1. Industrial units such as tractors, motor-driven railroad equipment, stationary power plants of various description, etc.—Chief advantages of Diesel power for such applications are: fuel economy, cheaper fuel, freedom from fire hazard, better cooling.

2. Marine installation—The same advantages apply; and, in this field, the Diesel has proved itself over a long period of service.

3. Motor trucks—The chief advantages are: fuel economy, freedom from fire hazard—particularly important in hauling petroleum products, inflammable liquids in general, explosives, etc.—better torque characteristics in high-gear work. This field seems to offer the most promising future in high production on the heavy-duty units, say from 3½ tons upward.

4. Buses—The same advantages apply as in the case

of the motor truck—except that applications undoubtedly would be restricted not only to larger units, but those operating constantly over long inter-city or interstate routes.

5. Passenger cars—This high-production field need not be considered in this discussion if, indeed, it should be considered any time in the immediate future.

### LIMITS TO EXTENT OF APPLICATIONS

Despite inherent fuel economy, there are many factors which operate to limit the extent to which Diesel engines may be used. The controlling element, by far, is the added cost of Diesel power which demands the ability to amortize the added cost out of fuel savings, within a short period of time. This is indeed a serious question, and should become more serious in view of the probable shifts in the fuel situation.

Right now the applications in the trucking field are limited to vehicles hauling up to gross weight limits imposed by various states, as for example, 34 tons gross in California. And even in this category, applications are further limited to vehicles covering about 30,000 miles per year.

It is a fact, however, that many trucks cover from 200 to 450 miles a day, and such equipment should justify Diesel power—even in somewhat smaller capacity ratings. Several well-informed observers have even ventured a guess, in recent correspondence, that Diesel power will ultimately extend to vehicles of 14,000 to 15,000 pounds gross weight used in long-distance hauling.

Despite the present high cost of Diesel power, correctly-chosen applications are claimed to amortize the added cost within periods variously estimated at between three to 10 months. Some idea of the magnitude of the added cost may be gained from the examples given below:

1. A large truck manufacturer charges approximately $1,550 more for a truck equipped with a four-cylinder 90-horsepower engine, and $1,735 more for a six-cylinder 125-horsepower Diesel.

2. An Eastern truck manufacturer charges about $1,000 additional for a heavy-duty chassis equipped with a six-cylinder 125-horsepower Diesel engine.

3. A mid-western truck manufacturer charges approximately $800 more for Diesel equipment on three-ton trucks and $1,500 more for six-cylinder trucks hauling gross loads from 70,000 to 100,000 pounds.

4. One of the truck manufacturers on the Pacific Coast charges about $1,000 extra on large 10-ton units equipped with six-cylinder Diesel engines.

5. One prominent engine builder making a line of high-grade heavy-duty gasoline units estimates that their new line of Diesels will probably run 80 percent higher in price than a gasoline engine of like displacement.

6. Another high grade heavy-duty engine builder estimates that the list price of his Diesel engines is about double that of a comparable gasoline engine, i. e., $1,800 as compared with $900.

Remember that these added costs are being safely amortized under present operating conditions. Remember, too, that the high cost of Diesel power is due to the newness of the development as well as the relatively small production volume.

This picture, undoubtedly, will change as demand grows; and it has been variously estimated by well informed Diesel engineers that, with reasonable volume somewhat comparable to that current in gasoline engine production, the cost of a high grade Diesel power plant should not be much in excess of 10 or 15 percent of the cost of comparable gasoline power.

The danger in assuming too wide a market for Diesel application lies in the fact that independent investigations show a rather low average yearly mileage for the gamut of vehicles in all kinds of service. For example, published I.C.C. statistics show that inter-city vehicles on the average cover about 15,000 miles per day. On the other hand, a survey of all classes and all sizes of operations conducted by the National Automobile Chamber of Commerce (now Automobile Manufacturers Association) several years ago yielded an average figure of only 7,000 miles per year. Roughly, if we assume an average saving of three cents per mile for fuel without any other operating expenses in excess of gasoline practice, we should require an average yearly mileage of about 35,000 miles to pay for the added cost. Smaller mileages would require a correspondingly greater period of time for amortizing the additional investment.

Looking at the tractor development, H. H. Howard of Caterpillar Tractor Company, in a paper entitled "Some Diesel-Tractor Problems" which he presented at the tractor and industrial power equipment meeting of the Society of Automotive Engineers early this year, reports that Diesel power cuts tractor fuel costs 75 to 80 percent.

### DETAILS OF PRESENT ACTIVITY

At the present writing the following American engine manufacturers have placed high-speed automotive Diesel engines on the market: Buba Company, American Diesel Engine Company, Cummins Engine Company, Hercules Motors Corporation, Waukesha Motor Company, and Sterling Engine Company. I have just learned, too, that another company that has been experimenting for several years expects to be in production on a line of automotive Diesels very soon.

Among the tractor manufacturers we may list the Cleveland Tractor Company, Caterpillar Tractor Company, and International Harvester Company—the last two building their own Diesel engines.

The following is a list of American motor truck manufacturers who are among those prepared to supply Diesel equipment when specified: Four Wheel Drive Auto Company, Gramm Motors, Inc., Kenworth Motor Corporation, Kleiber Motor Company, Linn Manufac-

turing Company, Robert Gotfredson Truck Company, Sterling Motor Truck Company, Ward La France Truck Corporation, Indiana Division of the White Company, Moreland Motor Truck Corporation.

Now just a few notes as to the number of units in service. In the first place, current reports to *Automotive Industries* indicate that by the middle part of 1934 more than 90 percent of all trucks over two tons registered in Germany were Diesel powered. This is a definite trend in all European countries, including England —where over 2000 Diesel powered vehicles are now in operation.

According to the report by Mr. Howard, mentioned earlier, 90 percent of the recent demand for heavy-duty tractor equipment in this country was for Diesels, and more than 2500 caterpillar tractors equipped with this type of power plant were sold during the past 2½ years. International Harvester Company has sold over 1000 Diesel units about evenly distributed between Trac-Trac-Tors and power units. This company, too, has found that the demand entirely outstrips their production facilities, and they estimate that for the coming year they will build in the neighborhood of 3000 units.

Cummins Engine Company reports that they have records of close to 500 automotive Diesel engines in service at the present time. Waukesha has sold between 1000 and 1500 Hesselman engines for use in industrial power units of every description.

## FUEL ECONOMY FIGURES

In the development of this paper I have collected a great mass of operating figures from many sources. These figures show graphically the tremendous savings that are being made by operators in various parts of the country. Naturally, the figures vary widely due to differences in the type of vehicle, conditions of operation, and in the methods used in computing economy. However, the fact remains that the operators of heavy duty equipment are saving anywhere from 60 to 80 percent of the fuel bill, i.e., paying only 20 to 40 percent of the previous bill for gasoline. I might point out that these comparisons are most significant, since they apply in practically every case to the operation of old equipment, i.e., on trucks which have been in use a number of years and in which the gasoline engine of known performance was replaced by a Diesel.

## MAINTENANCE

Maintenance cost in the operation of the American high-speed automotive Diesel engine is a moot question and one which, unfortunately, I am unable to discuss with any degree of confidence—due to the lack of figures and, principally, because of the lack of cumulative experience. On the whole, the few reports that have come to me indicate that maintenance is not a serious problem, although it is quite likely that trouble has been experienced in some instances. Reports from Europe seem to indicate that maintenance cost on the foreign engines runs about 30 percent higher than for their gasoline engines.

In this connection it would be quite apropos to mention the remarkable transcontinental run recently completed by the Burlington Zephyr. As you know, this train was built by Edward G. Budd Manufacturing Company, and equipped with a Winton Diesel eight-in-line of about 700 horsepower, operating at 750 r.p.m. I am told that the train covered about 14,000 miles on its barnstorming trip without incident or accident. No part of the injection system needed repair or cleaning during the run.

## TOTAL MARKET

For an estimate of the potential market for Diesel equipment I have used the registration figures published in the *Automobile Facts and Figures,* 1934 edition, as well as the 1934 statistical issue of *Automotive Industries.* In 1933 the total motor truck registration was 3,226,747 units. Assuming that Diesel equipment will be found economical only for vehicles in excess of 2½ tons capacity, we can get a little more closely to the actual market. According to *Facts and Figures,* the average yearly production of motor trucks of 2½ tons capacity and over was about five percent per year of the total for the last five years. Using this percentage, we can estimate that in 1933 there were approximately 161,000 trucks in operation that might fall in the category of Diesel equipment.

Yearly production of vehicles of 2½ tons and up has run from an all-time high in 1929, of over 54,000, down to 14,523 in 1933.

In addition to the foregoing, there is a total of 45,000 buses in common-carrier service in the United States. Of these 26,314 are in inter-city and intra-state service; but only 5300 of the latter are in interstate service, according to *Bus Transportation.*

The foregoing specifies the potential market for the Diesel engine, assuming almost 100 percent replacement of all vehicles in service. Obviously, this is untenable, and we may say that the real market is a certain small percentage of the yearly production of trucks and buses plus a relatively higher volume of replacement business. We may say, in general, that the market for the Diesel narrows down to those units that can yield a sensible economy in operation, consistent with the higher investment charge.

## FUEL SITUATION

As I said earlier, the future of the automotive Diesel seems to be undeniably linked with the availability of its fuel as well as the future course of fuel cost. It seems to me that the situation deserves the cooperation of refiners and the American Petroleum Institute—assuming, of course, that the demand for this type of fuel does not upset the general economic picture of the petroleum industry. It is on this point that we find the greatest controversy, but I have been assured by a number of petroleum technologists that there is nothing at all alarming in the situation that might be created

**TABLE 1**

**Comparison of Gasoline and Fuel-Oil Prices, in Bulk and Retail, for Various Localities**

| | Tank-Car Prices September 17, 1934 (Cents per Gallon) | Service Station Prices (Cents per Gallon) |
|---|---|---|
| **Oklahoma:** | | |
| Gasoline | 4⅝ to 5 | 18 (including tax 5 cents) |
| Fuel Oil No. 1 | 2¾ to 2⅞ | ..... |
| Diesel (28-30 deg. A.P.I. gravity) | 2¼ | ..... |
| **Philadelphia:** | | |
| Gasoline | 6¼ to 6¾ | 17.5 (including tax 4 cents) |
| Fuel Oil No. 1 | ..... | (8 cents for 100 gal.) |
| Diesel (28-30) | 4¾ to 5 | ..... |
| **California:** | | |
| Gasoline | 8 | 18 (including tax 4 cents) |
| Diesel (27 plus) | 2⅝ | ..... |
| **Chicago:** | | |
| Gasoline | 4½ | 16.8 (including tax 4 cents) |
| Fuel Oil No. 1 | ..... | (8.25, less than 100 gal.) |
| | | (6.75, 150 gal or more) |
| Diesel (28-30) | 2½ | (7.25, 150 gal. or less) |

by a moderately increased demand for certain types of fuel oils.

Since operating economy is almost the only consideration, it is axiomatic that the automotive Diesel must use the cheapest, most abundant type of fuel, and one which is readily available in all parts of the country. At present the straight-run fuel oil has been most suitable for this type of service, the No. 1 and No. 2 furnace oils being generally used on truck engines of the high speed type; No. 3 oil for medium speed tractor engines. However, due to a lack of understanding of the economic picture, some Diesel engineers have proposed designs which would require fuels meeting unnecessarily rigid specifications. This is a dangerous move, and it is estimated by some petroleum technologists that such fuels may cost more than good gasoline.

What is needed immediately is a thorough investigation of the fuel problem, and some quick action on the part of technical committees in the development of fuel specifications suitable for present day automotive Diesel engines. These specifications should give minimum requirements consistent with good operation, so as not to affect materially the present price structure. Some work already has been done along this line by the engineering societies; also in the formation of a special voluntary committee headed by T. B. Rendel of Shell Petroleum Corporation. The fact remains, however, that the introduction of new engines, as well as the expansion of the field, is far outstripping the work of these committees.

At the moment the price situation is most favorable to the automotive Diesel development, as is evidenced by an examination of Table 1 giving comparative prices of fuel oil and gasoline at a number of different points in the United States. As a matter of fact, the bulk delivered price is even lower than these figures in certain communities—or at least that was the case prior to the application of the petroleum code. However, current correspondence indicates that in California the price of specification fuel already has been increased 50 percent above the prevailing market price; and, if this is any indication of the trend, it may result in some leveling off between the bulk price of fuel oil and gasoline.

## TAX AND DISTRIBUTION

While very little has been said about the possibility of a highway tax on Diesel fuel, the fact is that a tax at least comparable with gasoline practice is inevitable. It is quite fortunate that in the early stages of this infant industry the fuel has been, and still is, tax free—thereby permitting the amortization of higher priced equipment. However, the tax is coming; no one knows just when, but it is safe to assume that it will be slapped on just as soon as there are enough vehicles on the road to make it profitable to do so.

Indeed, there is a great element of danger in the situation, unless the future course of the tax policy is carefully watched by all interested organizations. For example, in recent correspondence, I learn from a reliable source that some of the California legislators are considering an excess tax on Diesel fuel oil possibly in the neighborhood of double the gasoline tax — on the theory that this type of equipment will use only half as much fuel by volume and, therefore, should carry double the tax burden to produce revenue equivalent to that expected from the gasoline.

Distribution of Diesel fuel, naturally, is a vital factor in the ultimate development of this form of power. If a common type of fuel oil product is used, distribution should present no problem whatever, particularly in the case of fleet operations where the fuel is purchased in tank wagon lots. Specification fuel may present a real problem, although even this may not be at all serious in bulk purchases. In thinking about the distribution problem, I have ignored the question of retail service station distribution; while this may be a development in the future, it is hardly a practical consideration at the moment, particularly because the cost of fuel oil purchased in this fashion should be considerably higher than the bulk price, and would make it difficult to amortize the additional cost of Diesel equipment. It is of more than passing interest, however, to note that service station pump distribution has been established at least in one instance where a Diesel pump was installed in a service station in Los Angeles early this year. We are told that at that time the Diesel fuel was being retailed at 5½ cents per gallon as compared with a contract price of three cents per gallon, prevailing in California.

## FUTURE DEVELOPMENTS IN THE FUEL SITUATION

In considering the future trend of the fuel picture, I am starting first with the premise that there is an abundance of straight run fuel oils, and that an appreciable increase in the demand for this type of fuel will not affect the volume of cracking stocks needed for gasoline. This is another controversial element, and one that may be the subject of considerable debate. Some say that any increase in the demand for the straight run furnace oils will create a shortage, will affect the

availability of cracking stocks, and will cause the price of Diesel fuels to increase materially.

Several petroleum technologists with whom I have discussed this matter do not share this point of view. In fact, very recently the chief chemist of one of the large refining plants in the East told me that an increased demand for the straight-run furnace oils would have very little effect, if any, up to the point where the usage of Diesel fuel would amount to about 30 percent of total gasoline volume. If this be true, then there is very little to worry about; because it would take an extraordinary expansion in the Diesel field before we couuld hope to approach this break-even point.

If the major premise stated above is tenable, then we may assume that for some time to come there will exist a price differential of perhaps two to three cents a gallon between gasoline and fuel oil purchased in bulk—with a still greater spread in price as long as fuel oil is tax-free.

Suppose that the demand for Diesel fuel becomes so high that its price comes up to the economic limit; also that the fuel is no longer tax-free, but carries about the same tax as gasoline. It is believed that under these conditions the price of fuel oil still will run from one to two cents less than the bulk price of gasoline. However, let's assume that the price of the fuel oil is exactly the same as that of gasoline. What will be the result?

Under these conditions, the Diesel would rest on its inherent economy—which on the average amounts to 30 to 50 percent saving in fuel by volume. But since that time is a long way off and implies great expansion and a great shift from gasoline equipment to Diesel, it is reasonable to assume that, if and when, we have reached this phase of Diesel development, there will be a much greater volume of Diesel production — quite comparable, in fact, with present gasoline-engine production. And, under those circumstances it is estimated by Diesel experts that the price of the Diesel power plant will drop down within 10 to 15 percent over that of good high-grade gasoline engines. So, in the dim future, if we see the likelihood of fuel oil at the same price as gasoline, the Diesel engine still will have a great advantage in fuel economy, and still will offer an attractive investment for certain operating conditions.

**TABLE 2**
**Summary of Motor-Vehicle Statistics**

| | |
|---|---|
| 1933 total registration motor trucks | 23,827,290 |
| 1933 total registration motor trucks | 3,226,747 |
| Percentage trucks 2½-ton capacity and up (of total) | 5 |
| Estimated number of trucks in service, 2½-ton and up | 161,000 |
| Estimated yearly increment of trucks, 2½-ton and up | 20,000 |
| Percentage 2½-ton and up of total motor vehicles | 0.7 |

(Based on *Automobile Facts and Figures*, 1934 edition.)

## COMPETITIVE FACTORS

In considering any new economic development, it is well to take into account competitive factors that may have some effect on its future prospects. A number of such elements are present. First is the continual improvement in the gasoline engine; but while this is a factor, it is hardly likely that the gasoline engine can possibly approach the inherent efficiency of the Diesel engine. Another element is the development of special devices for burning cheap, heavy fuels in gasoline engines. Then there is the competition from a new source—the availability of new fuels, such as butane and propane, which may be burned in the gasoline engine.

We must reckon also with special engine equipment, such as the Waukesha-Hesselman engine—of which over 1000 have been sold for industrial purposes in this country, and which is designed to burn the cheapest grades of fuel oil. Again, during the course of the last year or so, several new systems have been developed for converting gasoline engines into solid-injection engines of moderate compression ratio operating with spark ignition. The special systems supplied by the Atlas Imperial Diesel Engine Company and Guiberson are examples of this type.

How far these competitive elements will encroach upon the expansion of the Diesel engine is a matter for conjecture.

## CONCLUSION

The foregoing more or less rambling discussion may be summarized briefly in the light of the following conclusions:

1. That there is an attractive market for Diesel engines on heavy-duty truck, tractor, and industrial equipment used more or less intensively.

2. Specifically, the truck market consists of a slice of the 161,000 vehicles now in service and a certain small percentage of the yearly increment of about 20,000 heavy-duty units.

3. The success of the development depends, to a large extent, upon improvements in the mechanical design of the engine, reduction in maintenance cost—at least to the point where maintenance is no more of a problem than it is with gasoline engines—and also the course of Diesel-engine cost.

4. Finally, we may say that the ultimate expansion in this field will depend largely upon the fuel situation. And in this connection I would recommend the following: *a*. Development of minimum acceptable fuel specifications. *b*. Reasonable economic control of the fuel price. *c*. Vigilant study of the tax situation. *d*. Development of channels of distribution for Diesel fuel. *e*. Closer cooperation between the petroleum industry and Diesel engine designers.

# *Report of the A. P. I. Committee on*

# Viscosity Standards

**T. G. DELBRIDGE**
***Chairman***

THE American Petroleum Institute Committee on Viscosity Standards[1] was created in 1922 for the purpose of cooperating with the National Bureau of Standards in establishing master tubes for the determination of Saybolt Universal and Furol viscosities, in developing directions for the operation of these instruments so that check results might be obtained, and devising a practical method for correcting the results obtained from any Saybolt Universal or Furol viscometer to give satisfactory agreement between *reported* efflux times for the same oil by different operators working with different instruments. This committee issued a detailed report in 1924[2] describing the work done in the establishment of standards.

### ALPHA AND BETA SAMPLES

From time to time this same committee has made sure that the standards were being maintained. In 1926 eight samples having a wide range of Saybolt Universal viscosities were distributed to seven cooperating laboratories. The results showed deviations from the average of as high as 4.2 percent. In 1929 it became evident that there were increasing differences between reports on the same oil from different laboratories. The comimttee, therefore, reviewed the subject to assist in re-establishing the industry on the basis of the standards developed in 1922-24. For this purpose the committee prepared large samples of two oils, one known as Alpha oil, which was to be used as a secondary reference standard for viscosities at 100° F. Saybolt Universal; and a second known as Beta oil which was to serve the dual purpose at a 210° F. Saybolt Universal and 122° F. Saybolt Furol standard.

These samples were prepared and stored with every precaution to avoid contamination in viscosity with time. The viscosities of the two oils were determined in the laboratories of the committee members, and the first results showed deviations as high as one percent for individual laboratories when compared to the average values of all members of the committee.

### ALPHA AND BETA VISCOSITIES

It was early recognized that variations between laboratories were just as likely to be due to variables in the accessories to the viscometer proper, and to differences in technique and interpretation of the wording of the standard method resulting from changes in personnel, as to actual differences in standard barrels. The A.S.T.M. standard method D-88 was, therefore, carefully studied, and a list of possible variables was made up—together with suggestions as to how their effect might be minimized. A general meeting was then held in Bayonne, New Jersey, in March 1930, at which representatives of six committee members carried out cooperative work—as a result of which the following individual values were obtained on the Alpha oil at 100° F., Saybolt Universal:

| Laboratory No. | Corrected Efflux Time (Seconds) | Deviation from Average (Percent) |
|---|---|---|
| 1 | 294.3 | —0.24 |
| 2 | 295.1 | +0.03 |
| 3 | 296.7 | +0.58 |
| 4 | 294.8 | —0.07 |
| 5 | 295.1 | +0.03 |
| 6 | 295.0 | 0.00 |
| 7 | 295.0 | 0.00 |
| 8 | 294.0 | —0.34 |
| Average | 295.0 | 0.16 |

This brought all of the laboratories into very close agreement, and subsequent work on the Beta oil at 210° F. Universal and 122° F. Furol gave results which were carefully considered by the committee at Atlantic City, in June 1930. Seven members or their representatives were present, and without dissenting voice it was agreed that the viscosities of the two oils were as follows:

Alpha oil at 100° F. Saybolt Universal
= 295.0 sec. ± 0.3 percent

Beta oil at 210° F. Saybolt Universal
= 148.5 sec. ± 0.3 percent

[1]The personnel of this committee is:

| | Laboratory No. |
|---|---|
| E. W. Dean, Standard Oil Development Co. | 1 |
| T. G. Delbridge, The Atlantic Refining Co. (chairman) | 2 |
| O. C. Bridgeman, National Bureau of Standards | 3 |
| K. G. Mackenzie, The Texas Co. | 4 |
| L. W. Parsons, Tide Water Oil Co. | 5 |
| E. B. Phillips, Sinclair Refining Co. | 6 |
| J. B. Rather, Socony-Vacuum Corp. | 7 |
| J. B. Terry, Standard Oil Co. of Calif. | 8 |
| A. E. Pew, Jr., Sun Oil Co. | |
| H. V. Hume, The Atlantic Refining Co. (secretary) | |

[2]Report of the Committee on Viscosity Standards, 1922-24, Amer. Pet. Inst.

The Saybolt Furol viscosity of the Beta sample was accepted as:

Beta oil at 122° F. = 116.0 sec. ± 0.5 percent.

The somewhat larger tolerance on values for Furol instruments seemed reasonable, as this instrument has not been as carefully standardized as has the Universal viscometer.

## RELEASE OF THE TWO OILS

The standard oils were then released to the industry with the values as given above, and to date somewhat more than 200 samples have been distributed. This number included six to foreign countries—England, Germany, South Africa, Canada, Czechoslovakia, and the Dutch West Indies being represented. Eighteen major refiners in the United States have checked their instruments against the oils, many of them at annual intervals; and no measurable change in viscosity outside of the above tolerances has been reported. Two United States government bureaus and quite a diverse group of consumer industries have also used the oils for calibration standards.

After the release of the Alpha and Beta oils, it was thought advisable to check the results of the above standardization by sending out a sample of unknown viscosity to the committee members and a number of other laboratories which had checked the Alpha standard. This was done in the fall of 1930, and the following results were reported by committee members:

**Oil No. 16,515—Saybolt Universal at 100° F.**

| Laboratory No. | Corrected Efflux Time (Seconds) | Deviation from Average (Percent) |
|---|---|---|
| 1 | 184.4 | —0.32 |
| 2 | 184.8 | —0.11 |
| 3 | 184.9 | —0.05 |
| 4 | 185.8 | +0.43 |
| 5 | 184.8 | —0.11 |
| 6 | 185.5 | +0.27 |
| 7 | 186.0 | +0.54 |
| 8 | 184.0 | —0.54 |
| Average | 185.0 | 0.30 |

The results reported by nine laboratories outside the comimttee showed an extreme variation of 0.81 percent and an avearge deviation of 0.38 percent from the average value of 185.0 sec. found by the committee.

These excellent results obtained by 17 widely separated laboratories, working under widely different conditions, indicate that the A.S.T.M. method is capable of giving results well within the tolerance of one percent as prescribed in the method.

With the exception of reports from individual members of the committee on the Alpha and Beta oils at approximately yearly intervals, no formal figures or the maintenance of the standard were obtained until December 1933—at which time an oil designated as A-33 was distributed, and the following results were reported.

**Oil A-33—Saybolt Universal at 100° F.**

| Laboratory No. | Corrected Efflux Time (Seconds) | Deviation from Average (Percent) |
|---|---|---|
| 1 | 235.2 | —0.08 |
| 2 | 234.7 | —0.29 |
| 3 | 237.5 | +0.89 |
| 4 | 235.3 | —0.04 |
| 5 | 235.6 | +0.08 |
| 6 | 234.7 | —0.29 |
| 7 | 234.2 | —0.51 |
| 8 | 236.5 | +0.51 |
| Average | 235.4 | 0.34 |

It is to be noted that laboratory No. 3 at the National Bureau of Standards deviates further from the average than any of the others. This was true in the case of the Alpha oil in 1929-30, and was sufficiently disturbing to warrant a cooperative check at the bureau to determine the source of the divergence. As a result, a meeting was held in March, 1934, at which representatives of six committee members were present. Some differences in technique, interpretations of the terms of the standard A.S.T.M. method, and equipment were found.

After two days of careful check and re-checking, two contributing sets of factors were definitely established: 1, ambiguities in the description of the A.S.T.M. standard viscosity method; and, 2, differences in equipment. Changes in personnel have possibly contributed to the above, particularly the first.

## ALPHA VALUES SINCE 1929

Actual values for the Alpha oil obtained on viscometer tubes which have been maintained as primary standards by committee members since 1929 were as follows:

| Laboratory No. | Corrected Efflux Time | |
|---|---|---|
| | 1934 | 1930 |
| 1 | 294.7 | 294.3 |
| 2 | 295.2 | 295.1 |
| 3 | 297.9 | 296.7 |
| 4 | 295.3 | 294.8 |

Ambiguities in the description of the method have been rectified in large part by re-writing the directions. The differences in equipment are being eliminated by more detailed specifications of the bath to be used in standardization work and by establishing a set of new viscometer tubes to serve as primary and secondary standards. The present master tube A-29 has several undesirable features. The proposed new standard tubes have been manufactured from especially hardened steel in the shops of one of the committee members who agreed to furnish four tubes as nearly identical as possible in physical measurements and calibrated to read 295.0 sec. on the Alpha oil at 100° F. when tested under Saybolt Universal conditions.

To insure calibration of all the new tubes under comparable conditions and against the standard value of

295.0 sec. on the Alpha oil at 100° F., a general meeting was held at Bayonne, New Jersey, June 5-8, inclusive, 1934. Twelve representatives of six committee members were present; and eight of the 12 took part in the actual physical testing, so that the personal factor in the results obtained was probably well averaged.

The first step was to determine the relationship between the master tubes of three of the committee members, using the Alpha oil. The following results were obtained:

| Laboratory No. | 1 | 2 | 4 |
|---|---|---|---|
| Tube No. | 37 | 476 | 492 |
| No. of tests | 14 | 12 | 18 |
| Average viscosity | 295.4 | 295.8 | 295.5 |

These values are slightly higher than were obtained in March at Washington, which is probably due to the use of a different bath with an open top. The values obtained, however, were within 0.2 percent of the established viscosity of the Alpha oil. The next step taken was to calibrate six of the new stainless-steel tubes against the committee's standard. This was done by placing tube No. 37 of laboratory No. 1 in the bath with three of the new tubes and determining the viscosity of the Alpha oil in each tube under as nearly comparable conditions as possible. The following results were obtained:

| Tube No. | 67 | 65 | 37 | 61 |
|---|---|---|---|---|
| No. of tests | 6 | 8 | 5 | 11 |
| Average viscosity | 295.1 | 295.4 | 295.1 | 295.4 |

Exactly the same procedure was repeated the next day with another set of three new tubes—retaining No. 37 as a control—with the following results:

| Tube No. | 72 | 71 | 37 | 56 |
|---|---|---|---|---|
| No. of tests | 5 | 5 | 7 | 5 |
| Average viscosity | 295.6 | 295.7 | 295.7 | 295.8 |

The most interesting point in these last two series of results is the apparently inexplicable variation in viscosity of the same oil in the same tube with the same operators and accessories. As far as variations between the six tubes are concerned, as compared to No. 37, they agree within 0.3 sec., which is only 0.1 percent. The four tubes which appear to be most nearly duplicates are No. 67, 71, 72, and 56. To be able to demonstrate closer agreement between any of the nine tubes tested will require a well-insulated bath—such as that being built at the National Bureau of Standards, more finely calibrated and graduated thermometers, and better stop watches, or some procedure for using more than one watch—to eliminate the known occasional errors in timing.

It is of interest to record the average values of all good determinations on the nine tubes:

| Tube No. | Average Viscosity |
|---|---|
| 476 | 295.8 |
| 492 | 295.5 |
| 37 | 295.4 |
| 67 | 295.1 |
| 65 | 295.4 |
| 61 | 295.4 |
| 72 | 295.6 |
| 71 | 295.7 |
| 56 | 295.8 |
| Grand average | 295.5 |

The above results on these new tubes were considered by the committee at Atlantic City in June 1934, resulting in an agreement that tubes No. 56, 67, 71, and 72 be set aside for the new U. S. standards. After a further exhaustive comparison of the above four tubes in the new standardization bath, with each other and with the present questionable master standard tube and bath, one will be chosen as the new U. S. master standard for Saybolt Universal tubes. This will be set aside at the bureau, and used only once a year for check purposes against the three secondary standards—one to be retained in the possession of the committee chairman and used only for annual comparisons with the master tube, and the other two tubes to be used at the bureau as working standards.

## FUTURE WORK

Future work of the committee, in addition to the comparative tests just enumerated, will include a careful determination of the relationship between kinematic viscosity and the Saybolt Universal scale, careful study of factors affecting Saybolt Universal viscosities at 210° F. which are not encountered at 100° F., and a survey of the status of Saybolt Furol standards and procedure.

The experience of the committee in this type of standardization work, which has revealed the desirability of amplifying the present A.S.T.M. method D88-33, will be transmitted to Committee D-2 of that organization for its use in re-writing the existing form, so that the industry may have the benefit of the higher accuracy which your committee has been able to attain.

# Denver Refinery

## *Specializes in* Road Oils

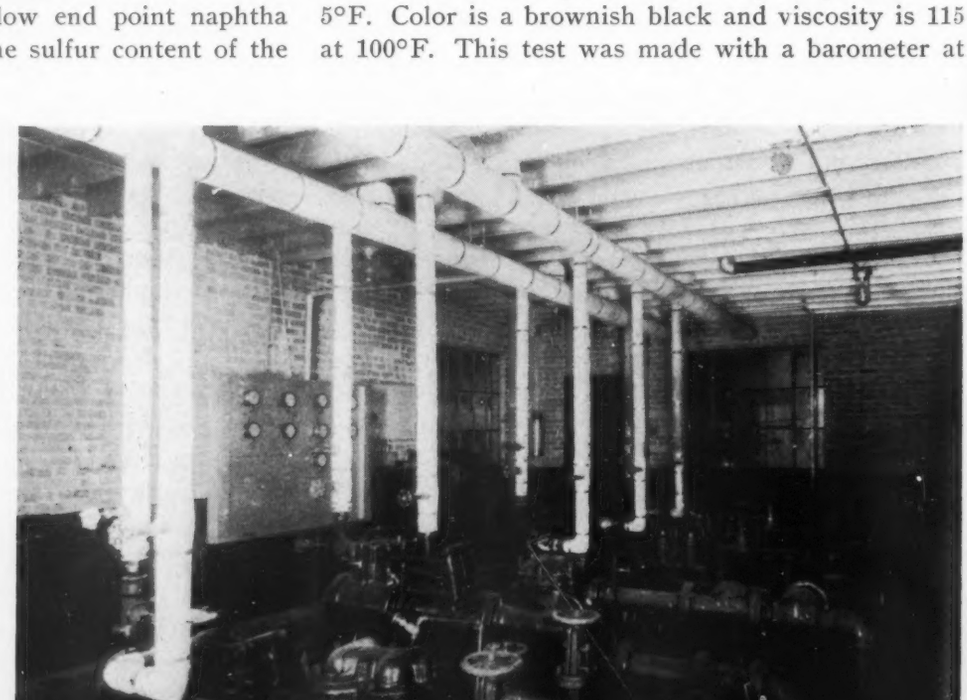
COLORADO-MIDLAND Refineries, Incorporated, situated on the Brighton Road north of Denver, was built two years ago and designed primarily for processing light oil produced in the Salt Creek field of Wyoming, from which the company manufactured the various grades of motor fuel, fuel oil and intermediate cuts. After operating in this manner for about 18 months the management of the company saw the possibility of supplying materials for "black top" highway construction, so a heavy black oil was charged to the still from which naphthas, Diesel fuel and road oil are produced. Only a few minor changes were necessary in the set up of the plant so that the heavy oil could be processed instead of the light oil formerly charged.

The crude now being charged is produced from six wells in the Black Mountain field in Hot Springs County, Wyoming. This field was discovered in 1922, but was shut in because of lack of market and distance from transportation. The crude is what is termed an intermediate base oil in which both asphalt and paraffin are found, but with asphalt predominating. Atmospheric distillation of the crude yields about 25 percent of low end point naphtha of good octane rating, but the sulfur content of the oil is close to three percent which makes it imperative that the naphtha recovered be treated before it can be marketed as a motor fuel.

After the refinery made arrangements to process this oil, the wells were placed on production, a pipe line laid to the nearest rail point and the crude shipped from Thermopolis to Denver in tank cars. The crude has the following characteristics upon distillation when using a Hempel column:

| Temperature | Cut per cent | A. P. I. Gravity of cut |
|---|---|---|
| 50°C.—122°F. | 0.3 | ... |
| 75°C.—167°F. | 1.3 | 70.9 |
| 100°C.—212°F. | 2.6 | ... |
| 125°C.—257°F. | 3.2 | 59.5 |
| 150°C.—302°F. | 4.0 | 53.2 |
| 175°C.—347°F. | 3.9 | 48.1 |
| 200°C.—392°F. | 3.1 | 44.3 |
| 225°C.—437°F. | 4.7 | 41.1 |
| 250°C.—482°F. | 4.7 | 37.8 |
| 275°C.—527°F. | 5.4 | 34.0 |

A. P. I. gravity of the crude is 24.3°, having a sulfur content of 2.93 percent with a pour point below 5°F. Color is a brownish black and viscosity is 115 at 100°F. This test was made with a barometer at



***Interior main pumphouse and control room***

***Refineries at Denver, Colorado. Continental Oil company's plant at the left and Colorado-Midland Refineries, Inc., in the right foreground***

586 mm, and the initial boiling point—or first drop—was at 116°F.

The contents of the crude by fractional separation are as follows:

| Content | Percent | A.P.I. Gravity | Viscosity |
|---|---|---|---|
| Light Gasoline | 4.2 | 70.9 | |
| Total Gasoline and Naphtha | 18.4 | 55.4 | |
| Kerosene Distillate | 4.7 | 41.1 | |
| Gas Oil | 17.7 | 33.4 | |
| Non Vis. Lube Distillate | 10.4 | 30.0-26.4 | 50-100 |
| Medium Lube Distillate | 10.3 | 26.4-22.1 | 100-200 |
| Viscous Lube Distillate | | | above 200 |
| Residuum | 38.1 | | |
| Distillation loss | .4 | | |
| Carbon Residue of Residuum | | 14.8 percent | |
| Carbon Residue of Crude | | 6.2 percent | |

Three separate products are manufactured by the company when processing this crude; naphtha—used for motor fuel when blended with natural gasoline, Diesel fuel, and road oil. Gasoline recovered from the process is more or less a side product while road oil is the principal one. The cuts taken from the oil falling in the range specified for Diesel fuel is more important than the gasoline because in the Rocky Mountain area trucks making long hauls are beginning to be equipped with Diesel engines. The gasoline removed as a first cut during the topping operation represents approximately 25 percent of the original charge, and has an initial boiling point of 198°F. with an end point of 400°F. It is being used unblended in some of the trucks hauling road oil and supplies to and from the plant, but to make a satisfactory automobile motor fuel, considerable natural is blended to obtain the desired front end volatility. The gasoline as it is condensed has a low gravity, being on an average of 50° A. P. I., but the octane rating runs close to 72.

The intermediate cut, removed by distillation, is subsequently separated into three grades, 28/30, 32/36 and 36/38 to be used as a fuel for Diesel engines. This cut in the rough represents approximately 38 percent of the original charge, making a total distillate recovery of 63 percent. Bottoms run to road oil represent about 38 percent of the charge, meeting the SC-3 road oil specifications, having a gravity of 12.6° A.P.I.

The black crude is charged to the plant at a rate of 1000 barrels per day, passing through a tower bottoms-to-charge tubular exchanger, where the temperature of the oil is raised to 400°F. From this unit, the hot oil enters the pipe still which is equipped with four-inch tubes and the temperature raised to 650°F., a point just a few degrees above where the black oil begins to crack at atmospheric pressure.

Leaving the pipe still the crude enters a fractionating column, 48 inches in diameter by 42 feet in height, containing 28 plates equipped with bubble caps. This column receives the hot charge from the pipe still at a point above the fourth bubble plate, counting from the base, while steam is introduced into the mass at a point above the bottom plate. The amount of steam used for this purpose is not

metered, but the volume arrived at by experimenting with the column when running to road oil bottoms, controlling the flow with a manual control valve near the entrance to the shell of the column.

As the vapors rise through the tower, fractionation takes place and a side cut is removed from the column on the fifteenth plate, counting from the base. This is the cut that is subsequently fractionated into three grades of Diesel fuel. This fraction is dropped from the side of the main column through a two-inch distillate line to a side stripper located near the base of the main column, where the lighter fractions coming off with the distillate are removed and returned to the main column.

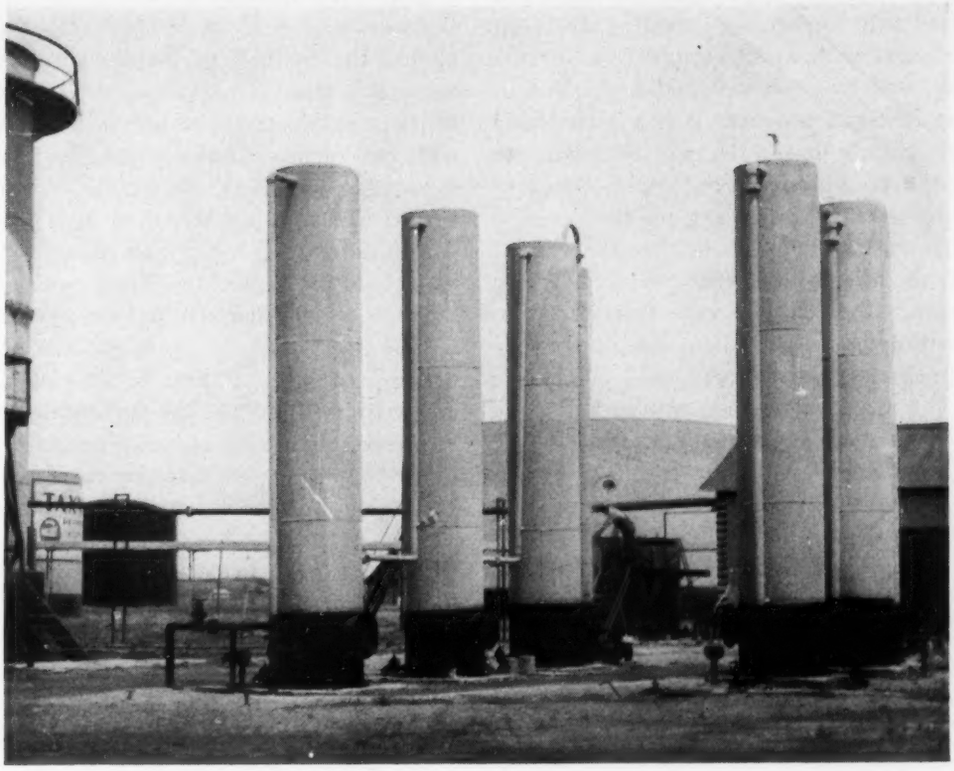
These vapors, together with those not taken off as a side stream, continue to rise through the height of the column and are finally removed as an overhead fraction through a 10-inch vapor line, the outlet of the tower being controlled to a temperature of 275°F. The vapors constituting the overhead fraction are carried to a bank of submerged coils placed in a condenser box located on the roof of one of the two pump houses. The distillate is conveyed from the condensers to run down tankage from where a portion of it is pumped back to the top of the column as reflux.

The side cut is withdrawn from the stripper and cooled in a series of submerged coils placed in a condenser box located on the ground near the pipe still. It was not elevated because the pressure of the column of distillate in the side stripper and the line leading to the cooling unit was found sufficient to force the liquid through the system and to the receiving tanks.

The overhead fraction after being condensed is passed through a continuously operated doctor contacting unit to sweeten the product before it is blended with natural. The majority of the original sulfur content of the crude remains in the bottoms but sufficient comes over with the overhead stream to prevent the product being used in internal combustion equipment without first being treated to doctor sweet and non-corrosive condition. Steam with which the plant is operated is generated in two water tube boilers which are oil fired. The fuel used is road oil, bottoms from the fractionating column. These boilers have a rating of 250 horsepower, and only one of them is operated at one time; the other being held in reserve and used alternately when either is found in condition requiring cleaning.

Water for the plant is produced from a shallow well near the rundown tanks, being found at 46 feet in sufficient quantities that it is only used once over the condensers. The overflow is led to a plant sewage disposal system and to waste. However, boiler make up water is taken from the condenser box in which the overhead fraction coils are submerged. It is not necessary to treat the boiler feed water. All the exhaust steam from the plant pumps is condensed and returned to the hot well.

The bottoms from the fractionating column after passing through the charge-to-bottoms exchanger are led to a large horizontal tank from which they are loaded hot to tank cars on a siding a few yards away. The market for the road oil produced by this plant is furnished by the Colorado State Highway Department which takes the output of the refinery.



# Continuous Treating

TAXMAN Refining Company, Wichita Falls, Texas, finishes all debutanized pressure distillate and straight-run gasoline in a continuous "doctor" treating system. Doctor solution has been used in this plant since it was revamped into a compact skimming and cracking unit from the old shell still layout in use when the plant was originally built. Only recently, however, has an attempt been made to recondition the spent solution so that it could be re-used with only the addition of a small amount of caustic and litharge each day. Previously when the solution had lost its strength it was drawn from the settling tanks and drained to sewer.

The cracked product manufactured in the refinery after the straight-run gasoline is distilled from the crude is passed through the new debutanizing-vapor recovery plant to control the vapor pressure, and under this process pressure, the stable product is given continuous treatment by washing with caustic. This part of the treating plant is separate from the final treater and is operated as a part of the debutanizing system. It was operated for the same results before the vapor recovery unit was completed in the spring of 1934. The pressure distillate is contacted in a column where the caustic is circulated by a motor-driven centrifugal pump. After settling to separate the gasoline and the caustic wash, the gasoline is directed to temporary storage before it is passed through the final treating plant.

The refinery at Wichita Falls is operated on North Texas and Panhandle crude, and the amount of straight-run gasoline removed from the crude charge and recovered in the "first flash" operation of the plant averages about 1200 barrels daily while the cracked pressure distillate coming from the "second flash" averages about 1050 barrels. Vapors recovered from the cracking operation, from the skimming accumulator drums, and the rundown and storage tanks amounts to an average of 4000 gallons each day; all of which is treated with sodium plumbite. The contacting apparatus in which the recovered high gravity gasoline is treated was built as an integral part of the vapor recovery unit and is operated continuously by passing the liquefied product through the contactors and columns under process pressure.

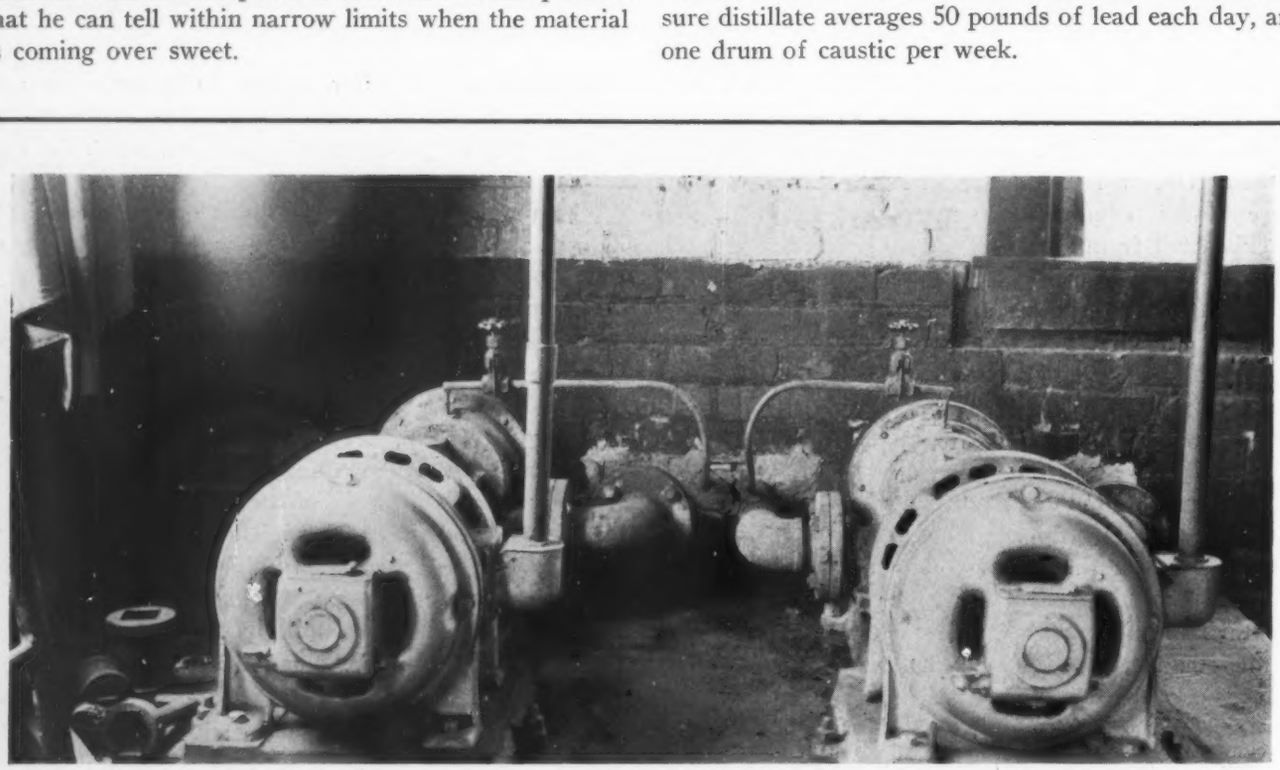
The systems in which the straight-run and pressure gasoline is treated are separate units and are usually operated so that these two products can be treated at the same time but through separate contactors and settling tanks. This plant, both for the straight-run

and the pressure distillate, is located near the old batch agitators, now used only for kerosene treating, and consists of three columns with a single contactor for the pressure distillate, and two columns and a single contactor for the straight-run product. It has been found from plant investigation that it is only necessary to contact each of the two products once with "doctor" solution and the three tanks, or towers, for the pressure distillate, and the two for the straight-run are used for settlers only. Neither of the two products receive any after-treatment, either caustic wash or water bath. The straight-run product is picked up by the treating pump without previous pre-treatment, and enters the final storage doctor sweet and non-corrosive with only the one contact. The average time required to pass the 1200 barrels of straight-run gasoline through the 11-plate contacting column and the two settling tanks is about 5½ hours, requiring an average of 800 gallons of regenerated doctor solution to accomplish the desired results. The doctor solution is circulated with the gasoline by a motor-driven centrifugal pump.

The cracked product to be finished after the continuous pre-caustic wash, is picked up from the temporary storage by a 12 x 10 x 14 duplex steam pump, with the sulphur pot located on the discharge. The gasoline stream enters the contacting column along with the circulating doctor solution, handled by a centrifugal pump the same size as that used in straight-run treating, and flows through the three settling columns and to storage. Tests are all run on the product in process at the plant laboratory, but the operator has become so familiar with the composition and color of the product that he can tell within narrow limits when the material is coming over sweet.

While the method of contacting the product, both skimmed and cracked, is similar to that used in other plants, the method of regenerating the spent doctor solution differs in some details. The regenerating unit consists of three tanks set with the upper rim flush with the surface of the ground and two others set on elevated foundations. When the solution has been used until it appears necessary to regenerate, it is drawn from the treating system and placed in one of the tanks. The treating tanks are fitted with submerged coils through which steam is passed so that the filled tank will be brought up to about 180°F. Blowing with air is begun, cautiously at first because of the foaming tendency of the solution, but increasing the stream of air at intervals until the mass in the tank is in a high state of turbulence. This state is continued during the day while the operator is on duty, and then the material is transferred to another tank in which it is treated in a like manner the next day. When operating on North Texas crude, it requires about 800 gallons of solution to treat the straight-run product, and when the plant is skimming Gray County crude, double that amount is required.

The spent solution is very dark when it is drawn from the treating tanks, and by continuing with the regenerating process, it finally becomes a dark cherry red without any apparent suspended matter. Then the solution is built up by the addition of fresh caustic having a gravity of about 16° Be. and some lead. The amount required to regenerate and build up the solution used for both the straight-run and cracked pressure distillate averages 50 pounds of lead each day, and one drum of caustic per week.



***Centrifuge pumps driven by motors circulating doctor solution for treatment of both straight run and cracked gasoline***

# Control *of* Maintenance Costs

L. C. TRESCOTT

WHILE organization and planning for the control of production costs have gone forward rapidly, in many cases the matter of maintenance has been swallowed as a general item, more of a nuisance than anything else, about which nothing can be done. Too often, particularly in the smaller refineries, no real effort is made to segregate maintenance costs. The master mechanic works himself almost into the grave with nothing on the record to show for his toil, and many times the costs due to improper maintenance will run to a high figure, particularly if the loss of production due to such methods were to be charged against maintenance. It is too common to accept this work as an uncertain factor, as a thing to be accomplished by much wild rushing, with the expenditure of large volumes of expressive language. More often than not the work is just a jumble of emergency conditions where no one makes any effort to foretell just what will happen next.

Is it possible to plan and route maintenance work? Can we say that on such and such a day this machine will be shut down, and on that day we will replace the weak drive chain? What possible control have we over emergencies?

In most plants the maintenance work falls along the lines shown in Figure 1. Even in the small plant this work should be centralized if its costs are to be controlled, and the first step in such a control effort is to make sure that all lines of all maintenance work pass through the master mechanic's hands.

Maintenance work can be broken into the following classes:

1. *Preventive Maintenance.*—Inspection and repair of equipment to prevent breakdowns.
2. *Corrective Maintenance.*—The repair of equipment that has failed in service.
3. *Routine Maintenance.*—Oiling, packing pumps, etc.
4. *Routine Plant Maintenance.*—Sweeping, cleaning, painting.
5. *Replacement Plant Maintenance.*—Replacement of floors, roofs, windows, etc.
6. *Plant Rearrangement Work.*—Installment of new equipment, minor plant changes, etc.

With the exception of item 2, corrective maintenance, it will be seen that the rest of the maintenance operations are of such a nature that they may easily be planned ahead of time and laid out along routine lines; that the costs may be easily segregated and controlled.

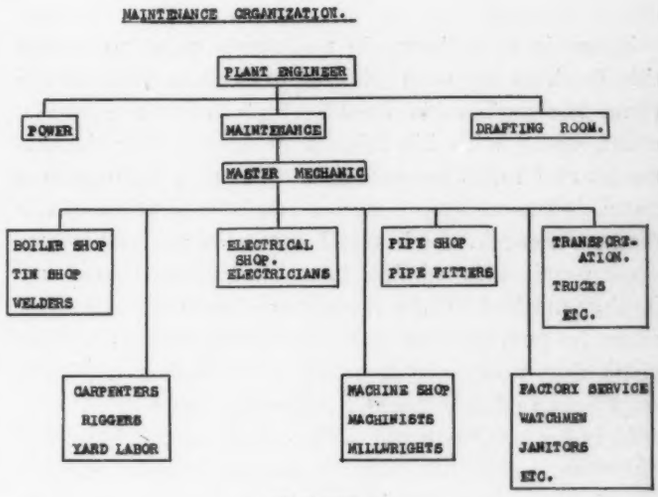



**FIGURE 1**

In the oil refinery items 1 and 2 are beyond question the most important, and of these item 1 should take first place. But, as a matter of fact, in not many refineries is there a regular inspection procedure, placed on a routine basis, with records that supply interested parties with an exact knowledge of every piece of equipment. It is fairly clear, however that if this be done, item 2 can also be brought under a planned control and much of the nightmare be taken out of the master mechanic's work.

It is true that many plants have an inspection of a sort. The operators may keep an eye out for equipment that is slipping. If they think of it the matter is reported. But such responsibilities should not be pushed on the shoulders of the operators. Every plant, no matter how small, can afford a man whose job is to make a regular inspection of equipment, and report on his findings. Equipment seldom goes down without warning. Rather the wear is gradual; so gradual that the operator not looking for trouble may miss it altogether, but in more cases than not a trouble hunter can pick up weaknesses long before a breakdown. The report of this goes to the men in

charge, and it is possible to plan the repair, estimate its cost, and carry out the work at such a time that it will not interfere with regular production.

In a large organization it is of course possible to assign a man to a single definite line of work. There is sufficient equipment that the entire time of one or more men can be devoted to plant inspection. In the smaller plant this work must be handled by a man who puts only a part of his time on it. However it is done, there are two points to be emphasized: First: The inspector should be a man who fully recognizes the importance of his job. Second: the management itself should see this importance and recognize it as more than just an additional bit of red tape.

There is a tendency in too many cases to assign this work to any man who happens to be loose at the time. He makes his rounds, looks over the equipment, visits with his friends in the various departments and turns up just about quitting time with a more or less complete report on the condition of the plant. In cases which stand out as in need of immediate repair he probably has some notes. These are further marked by the master mechanic for attention when he gets around to it and the inspection is over until the next period, when some other available man is picked and the procedure repeated.

It is far better to place this work in the hands of one man, preferably one of the older, more experienced mechanics. Give him a card for each piece of equipment with a place to note his findings, and make him responsible for the results of the inspection. This man should make every inspection. A man gets to know equipment and what to expect of it. His cards show when the liner in this pump was

| EQUIPMENT INSPECTION. |
|---|
| DEPARTMENT: |
| EQUIPMENT: |
| PLANT NO.: |
| SERVICE: |
| DATE INSTALLED: |
| REMARKS: |

(Reverse)

| REPORT OF INSPECTIONS. | | | |
|---|---|---|---|
| DATE | INSPECTOR | CONDITION OF EQUIPMENT | REPAIRED |
| | | | |
| | | | |
| | | | |
| | | | |

**FIGURE 2**

EQUIPMENT REGISTER FORM.

| EQUIPMENT REGISTER. | |
|---|---|
| EQUIPMENT: | |
| DATE PURCHASED: | FROM: |
| MFG. NO.: | OUR NO.: |
| LOCATION: | |
| DATE INSTALLED: | |
| ENGINEERING DATA: ( Sizes, Auxilliaries, etc.) | |

**FIGURE 3**

changed and when the valves on that one were faced. He can make a fair guess as to when it will be necessary to repeat the job and be on the lookout for it. The cards with his notations can be placed on file in the master mechanic's office and be made the basis for planning and laying out the major part of the plant maintenance work. A glance through the cards will show pretty well what may be expected. The relative importance of the various jobs may easily be decided, and there will always be time to handle them at the lowest possible cost rather than at a high emergency cost.

A type of inspection form is shown in Figure 2. This shows the department in which the equipment is located, and data on the equipment itself. The type of service on which it is used should also be noted as well as the date on which it was put on that service. In the refinery, pumps and equipment have a long life, and before they are discarded may serve several purposes. An acid pump, for instance after a certain period in that service is often transferred to less corrosive work. It is of value to know when a piece of equipment was placed on a certain job and how well it stood up under the strain. A new card should be made out with each change of service, and a proper record of the change made on both cards. In this way it is possible to keep a complete history of any piece of equipment. Pipe lines of any length may be listed as separate pieces of equipment. Short connecting lines may be listed as auxiliary to the tanks, agitators, etc., which they may connect. Buildings or any other items requiring maintenance should have their cards and a record of their condition kept on file. In the last column of the record the fact that needed repairs have been completed may be noted.

In connection with this inspection record, there should be kept in the master mechanic's office a plant equipment register. A form for this is shown in Figure 3. The information on this should cover all necessary engineering and installation data. This may also

be kept as a cost record in which case it takes the form of Figure 4. This form gives detailed costs of the purchase and installation. It also shows the value of any permanent changes or improvements as well as the depreciated value.

It must be noted that this item of permanent improvements does not cover routine upkeep or repair. The figures shown under that head cover changes or such major repairs as may constitute capital charges. Maintenance costs are a part of general factory expenses and are carried as such.

There seems to be no set rule for depreciating refinery equipment. With the swift advance in processing methods equipment is obsolete long before it is worn out. Some concerns insist that certain types of new equipment must pay for itself in two or three years. Much of the standard equipment is depreciated over periods of 10 or 20 years. It must be noted here that over a period of years, records such as are proposed should form a basis for determining the actual life of any piece of equipment as well as the cost of keeping it in service.

Having put in effect an inspection system and collected information on the state of the plant equipment, how is this data to be used? The first step in a maintenance job, if it is to be under control, is a maintenance order of some sort. Maintenance costs are a part of general factory overhead expense and the usual rule is that the order shall be issued by the production department to which this expense is charged.

After an inspection the production foreman should be informed as to the equipment in need of repair. He should be consulted as to the best and most convenient time to make the repair and should be ready at that time for the work to proceed. Finally, he issues the necessary maintenance order, or request for work to be done.

A form for such an order is shown in Figure 5.

EQUIPMENT REGISTER FORM WITH COST DATA.

| EQUIPMENT REGISTER. | | | | | |
|---|---|---|---|---|---|
| EQUIPMENT: | | | | | |
| PURCHASED FROM: | | | | | DATE: |
| PURCHASE PRICE: | | FREIGHT : | | | |
| INSTALLATION COST: | | | | TOTAL COST: | |
| DATE | VALUE | PERMANENT IMPROVEMENTS | TOTAL VALUE | DEPREC. | NET BOOK VALUE. |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

FIGURE 4

MAINTENANCE ORDER FORM.

| MAINTENANCE ORDER. | | NO. |
|---|---|---|
| THE MAINTENANCE DEPARTMENT WILL PLEASE PERFORM THE FOLLOWING WORK: | | CHARGE ACCT. NO. |
| DESCRIPTION: | | |
| | | |
| | | |
| | | |
| DATE: | DEPT. | SIGNED: |

FIGURE 5

It is simply a request on the master mechanic that he do certain work, giving necessary details and the number of the account to which the work is to be charged.

It is at this maintenance order stage of the work that much confusion is too often brought about. Most plants have a system of maintenance orders, shop orders, or mechanical orders as a step in recording costs, but often this order is not issued to the head of the maintenance department but goes direct to the shop foreman who is to do the work. The production foreman decides that there is repair work to be done and starts issuing orders to cover it. As a result the carpenters, boilermakers, pipe fitters, and laborers may all arrive at the same time to find that one crowd cannot move until the other is out of the way, and that in all probability, materials for the work are not on hand. The procedure then is for all to wait until someone in authority comes along and sends most of them away. The time, of course is charged to the job. And it is surprising in how many plants, both large and small, that this sort of thing is the rule rather than the exception.

If there be no mixup of this sort, workmen may came and do the job while the men at the head of the maintenance work will know nothing about it until by some route or other the maintenance orders may reach them days after the work has been completed.

Too often any planning that may be done for the job is done by the production foreman. He may or may not be qualified to handle the mechanical work. In any event he has a job of his own. He knows nothing and cares less of the work being done by the maintenance department. Under these conditions there is a constant robbing of Peter to pay Paul in the maintenance end, and the costs go up in their own sweet way. And the master mechanic wonders why he talks to himself and why, in the quiet of the evening, he undertakes to talk back to his wife.

The maintenance order should go direct to the master mechanic's office into the hands of a clerk or an assistant who issues the necessary orders to the various shop foremen. In most plants there is a limit

ESTIMATE FORM.

| ESTIMATE OF: | | | | |
|---|---|---|---|---|
| | LABOR | MATERIAL | OVER-HEAD | TOTAL |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| CONTINGENCY | | | | |
| ESTIMATE BY: TOTAL. | | | | |
| DATE: | | | | |

FIGURE 6

on the amount that can be spent without authorization by higher authority. The master mechanic's office can get the necessary approvals quickly and get the work under way in the shortest time possible. If men must be taken from other jobs this can be done in such a way as to cause the least interference with other work. Where necessary, estimates can be prepared. Materials and men can be moved to the job as needed and the maintenance department is in a position to see that the work gets a proper supervision. Regardless of the size of the job it can be planned and can be kept under control, which after all is the proper function of the master mechanic and his assistants. They are not expected or allowed to handle the production activities of the plant and by that same token it should not be in the province of the production foremen to lay out maintenance jobs.

The master mechanic should primarily be an organizer. At best maintenance work will not always follow set lines. There will always be emergency jobs which will disrupt the best laid plans. He must often reorganize his entire working force on short notice and this is all the more reason why all job orders should pass through his hands. The master mechanic must himself keep in mind that his job is to organize, to plan, to keep himself clear for emergencies, and not to spend his time simply as a driver. The average foreman of a mechanical shop is usually a man of some service with the company. Generally he knows his job and makes an honest effort to get it done. Such a man rightly resents undue interference with the details of his work. Particularly he resents the attempts of some young clerk to stand on his neck without good reason, but on the principal that to get things done one must howl as loudly as possible, and make things hot for the fellow who is trying to get ahead with the job. Still further the foreman resents it when, from his point of view, the said clerk may not know a gate valve from a monkeywrench.

## COSTS

In times past it has been the custom to use costs from a profit and loss viewpoint alone. Cost figures seldom came out into the open except on a business statement of some sort, showing in a general way whether the expense of manufacture was high or low. Now, however, it is the custom to use detailed cost figures as indicators of efficiency in all the production details of a business. Costs are rendered not for accounting purposes only, but for use in pointing the way to process improvements, for increasing yields, for cutting down wastes. Detailed costs show the sore spots of a business clearly, and as they apply to production, so they may be applied to maintenance.

Maintenance costs are subject to two general interpretations. They are interpreted for strictly accounting purposes, or they are interpreted by the management and by the master mechanic for application to plant operations.

Whenever possible the cost of labor and material for each job should be estimated. This is really the first step to control costs. For this purpose the estimate should be as close as possible. In cases where it is necessary to have money appropriated for a job, estimates must be made large enough to cover any contingency in order that the money appropriated will be sufficient to cover the cost of the work, but an estimate made for the purpose of cost control should be as tight

MAINTENACE COST FORM.

| MAINTENANCE COST. | | |
|---|---|---|
| MAINTENANCE ORDER NO.: | | CHARGE ACCT. NO. |
| DATE. | MATERIAL | AMOUNT |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | TOTAL | |

(Obverse)

| LABOR | | | | | |
|---|---|---|---|---|---|
| DATE | HOURS | AMOUNT | DATE | HOURS | AMOUNT |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| TOTAL | | | TOTAL | | |

FIGURE 7

as it is possible to make it. Figure 6 is a convenient form for this purpose.

There will be no attempt here to go into the matter of time keeping or other accounting or cost keeping methods, except to say that the labor and material going into each job should be segregated under its proper account number by the cost department and the totals for each day should be sent to the master mechanic for his records. A form for this purpose is shown in Figure 8.

EQUIPMENT MAINTENANCE RECORD.

| DATE | DESCRIPTION | MATERIAL | LABOR | OVER HEAD | TOTAL |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Note: This may be carried as the obverse of the Equipment Register form.

**FIGURE 8**

The maintenance order, the estimate form and the cost record should all be of the same size. They can be clipped together so that all information regarding that particular job is held for reference at any time. In this way it is easy to keep close tabs on the costs and see that they follow the estimates. A comparison between the two also provides a valuable basis for other estimates. Some concerns have reduced this estimating to a routine with tables of standards covering various "types" of maintenance operations. Such a practice is not hard to set up and saves considerable time.

Another record of value to the master mechanic is an equipment maintenance record which may well be carried on the reverse of the equipment register. This is shown in Figure 8. The figures carried on this record are for the information of the master mechanic on the cost of maintaining the particular item covered by the card.

In studying costs the fact must be kept in mind that it is not just to the figures that one must go. Cost figures represent the ultimate effect of various causes and if they are to be controlled or changed one must go all the way back to those causes. Unduly high maintenance costs call for further investigation. Is the equipment overloaded? Is it suited to the work it is doing? Is it properly installed? Is it worn out and should it be replaced? Have the proper materials been used in its construction? Is it receiving proper attention? These questions and others come up. When cost figures point the way they are often more easily answered than otherwise. At least they cannot be ignored. And a satisfactory answer will mean lowered maintenance costs, increased service, and a lighter burden on the master mechanic himself.

The foregoing applies to the control of maintenance costs involving construction or repair work of any sort. In matters of routine maintenance such as oiling, the packing of small pumps, etc., the work is often cared for by the plant operators. As a rule the small amount of labor involved does not warrant recording it as a maintenance cost, particularly as the work is charged against the production department concerned. However, the materials issued for maintenance purposes to each department should be reported regularly to the master mechanic by the storehouse. The cost of this material is covered by general maintenance charge against the production department concerned but it should be a part of the duties of the maintenance department to scrutinize such costs and require an accounting for the materials used as will be satisfactory to them. Such a practice will cut down a surprising amount of waste in packings and other maintenance materials.

The oiling of refinery equipment is usually done by plant operators. Where there is much equipment to be oiled it sometimes pays to have a man make regular rounds through the plant and look after it. This brings both the labor and materials under the control of the maintenance department and may effect a considerable saving in oil.

In most refineries the oiling of electric motors is usually cared for by a man from the electrical department. It is also profitable to clean the motors regularly, inspect bearings, etc. This should be a part of routine maintenance.

All of this routine maintenance is of course charged against the department in which it occurs. The master mechanic may not be particularly interested in the distribution of maintenance costs, but he should be interested in, and responsible for their control. In so far as possible this control should be centered in his office and not spread over the various production departments.

The maintenance department should exercise close control over all maintenance materials and supplies. A part of this control should be a study of plant requirements for supplies, for spare parts, etc., so that the variety of parts, sizes, etc., may be kept small. Plant design should be so standardized and care should be taken that sizes and styles of chains, gears, pipe fittings, and other equipment parts will be interchangeable in as many places as possible.

The storehouse should keep the maintenance department informed as to any shortage of the supplies in which they are interested, and also of the building up of any surplus along the same line. While surplus stocks should be kept down, this does not mean that supplies should be allowed to run too low. Emergency shipments, like emergency repairs, run the costs up.

Nothing is more disgusting than to have a job held up, with possibly a considerable loss of production, for the want of a two-dollar part, and it is a part of maintenance control to keep this from happening.

While the purchasing and storing of supplies is generally kept in the hands of the purchasing department, arrangements should be made so that the maintenance department can exercise control over the stocks in which they are interested. A practice which causes much trouble is the purchase of supplies for some special purpose and then issuing them on some other job, with the result that there is a shortage and a holdup of the job for which they were bought. Supplies purchased for a certain job should be earmarked for that job and should not be allowed to go out on any other, unless it be done with the master mechanic's permission.

In connection with supplies there is always the matter of the use of salvaged material. While there is much material that can be salvaged, every precaution should be taken that it is fit for the service on which it is to be used. All such materials should undergo rigid tests. It is an expensive and sometimes dangerous experience to put a salvaged valve in a line and have it fail. Not only the cost of the valve is involved, but the expense of putting it in and tearing it out again, the possible expense due to a shut down while the work is being done, and the possible loss due to accidents. Unless salvaged material be put back into almost new condition it has little value. Valves in particular are difficult to refit unless the work is in the hands of experts. For this reason the equipment of the salvage shop should be of the highest quality and only the best and most experienced workmen should handle the job.

It seems, then, that maintenance costs can be brought under some sort of control without the use of too much red tape. This means the centralization of all maintenance work and maintenance material under the control of the maintenance department. It means that emergency repairs must be cut to a minimum by means of a definite inspection system, regularly carried out by qualified mechanics. It means the establishment of a routine by which all maintenance jobs are brought to the maintenance department where they can be planned and laid out with real cooperation with the production departments. Data on each piece of equipment should be collected by means of the equipment register, and the maintenance cost of each should be segregated so that they may be studied and interpreted for cost reduction, for the reduction of waste in labor and materials, and for the improvement of operating conditions.

Most plants cover some of these items, but if maintenance costs are to be dragged out into the light of day and brought under some sort of control, they should all be covered. This does not involve additional clerical work or red tape. More often than not it simply requires the coordination of methods already in use to bring out the costs for this particular purpose.

The forms shown are not presented as being ideal for every case. Rather, they illustrate the ideas which form the basis for proper cost control and any system of forms which carries out these ideas will do as well. And once it is decided just what data is wanted it is easy to devise a form to collect it. Figure 9 shows the organization for cost control as tied together by these forms.

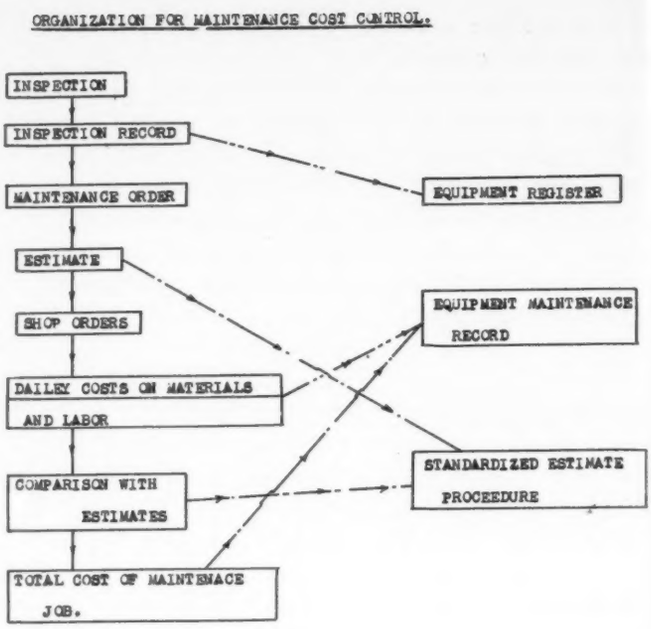


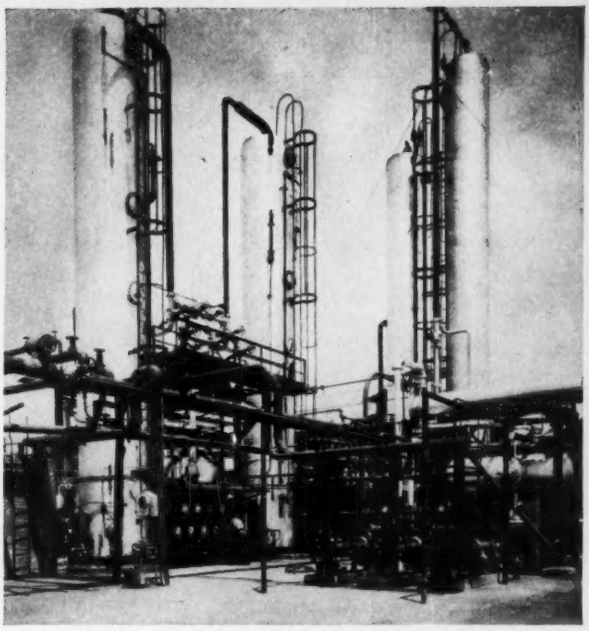

**FIGURE 9**

How will all this help the master mechanic, particularly the man in the small refinery? Probably it will control costs, but has he the time to sit in the office sorting over a bunch of cards?

According to too many pictures when a man takes over a job as a plant master mechanic he gives up all hope of that night's repose which theoretically he has earned, and in the course of his work it is taken for granted that he will develop a disposition which seriously threatens his chances for a happy hereafter. He is never done. They never cease hounding him. The cause of all this lies in the fact that too large a percentage of his jobs are of an emergency nature. Just when his gangs get one job nicely under way they must be torn loose and thrown into some new breech. There is no time for real planning.

Give the man a system by which breaks may be caught before they occur, a system by which qualified assistants can take petty details off his hands; a system by which he can tell exactly where every job stands without carrying it in his head. Give him costs that are worked up for his purpose; costs that apply to all maintenance items, not just a part of them; costs that point the way to improvement, that give him a real control of his job. On the basis of actual facts brought to him by a dependable inspection system, he can plan his work. In facing the facts instead of always holding himself in a position to meet the unknown, he is placed where he can control that work and directly control its costs.

# *From* TAMPICO *to* BAKU *refineries build with* CHAPMAN VALVES

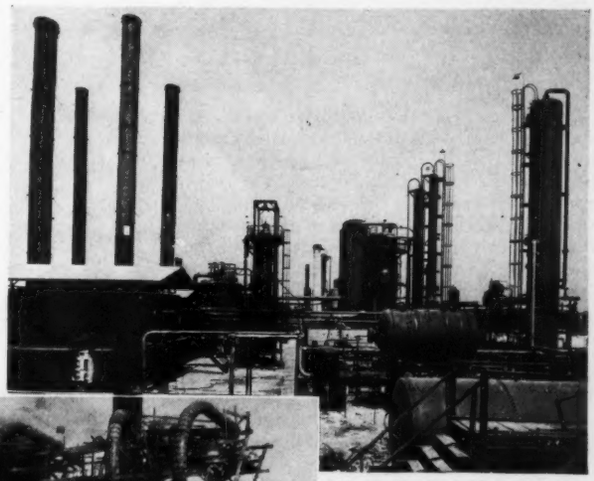


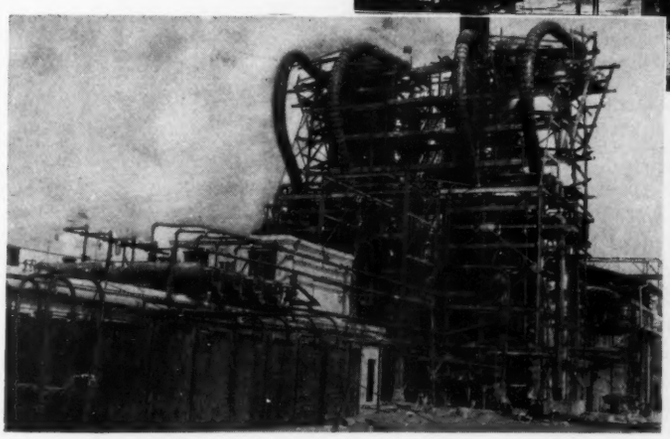
**IN MEXICO**—Chapman Valves insure long life and low maintenance costs in this new cracking plant at Tampico.

These new refineries in Russia, Mexico, and the United States embody the latest process developments and all are built for peak efficiency. To maintain this efficiency and to keep replacements and maintenance at rock bottom, the builders selected the best in plant equipment. For valves they picked Chapman.

It's the same throughout the Oil Industry. Wherever valves must stand up under high pressures, intense heat or cold and the destructive effects of corrosion, the preference is strong for Chapman Valves. For Chapman has developed valves for every specific refinery and gasoline plant application.

No matter how tough your service, you will find Chapman equipment built to fit... a complete line of gate, globe, angle, and check valves and fittings, in all sizes, for pressures of 150 to 1500 lbs. and temperatures from 50 degrees below zero to 1000 degrees above. For low maintenance costs follow the example of the world's leading refiners and write "Chapman" into your valve specifications





**IN U. S. A.** (*Above*) Spartan Refinery at Shreveport, Louisiana, U.S.A., in which Chapman Valves eliminate valve replacement worries.

**IN RUSSIA** (*Left*) Photograph taken during the erection of a refinery at Grozny, Russia, for which the builders selected Chapman Valves.

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## The CHAPMAN VALVE MANUFACTURING COMPANY

INDIAN ORCHARD, MASSACHUSETTS

# SCIENCE AND TECHNOLOGY

*Abstracts prepared in co-operation with the*

**REFINER AND NATURAL GASOLINE MANUFACTURER**

*by*

**THE LESLIE LABORATORIES**

**Traver Road, Ann Arbor, Mich.**

*under the supervision of*

**DR. E. H. LESLIE and DR. H. B. COATS**

*The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.*

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## Fundamental Physical Data

**Knocking Characteristics of Hydrocarbons.** W. G. LOVELL, J. M. CAMPBELL, AND T. A. BOYD. *Ind. Eng. Chem.* **26** (1934) pp. 1105-8.

Previous publications from the General Motors laboratory have described the knocking characteristics of a large number of hydrocarbons as determined in solution in gasoline. This paper reports the knocking characteristics of individual hydrocarbons alone and not in solution. The data recorded in the literature on this general subject are briefly reviewed. The authors extend this information to include 103 hydrocarbons, including paraffins, olefins, naphthenes and aromatics. The measurements are expressed in terms of engine compression ratios at incipient knock under definite conditions of engine operation. These critical compression ratios vary over a range of about 14 ratios. The qualitative general correlation between knocking characteristics and molecular structure previously found for the hydrocarbons when measured in dilute solution holds in general, but there are some notable exceptions. These arise from the fact that the compression ratio of a mixture of two compounds is not always directly proportional to concentration.

**Heats of Combustion and of Formation of the Normal Paraffin Hydrocarbons in the Gaseous State, and the Energies of Their Atomic Linkages.** FREDERICK D. ROSSINI. *J. Research Natl. Bur. Standards* **13** (1934) pp. 21-35.

From the recently obtained data on the paraffin hydrocarbons from methane to normal pentane inclusive, reliable values are calculated for the heats of combustion of all of the other normal paraffin hydrocarbons in the gaseous state. The values so determined are linear, with the number of carbon atoms above, not below, normal hexane. The deviations from linearity are given. The author generalizes as follows: "In any organic molecule containing a normal alkyl group of more than five carbon atoms, the addition of a $CH_2$ group to form the next higher normal alkyl group results in an increase in the heat of combustion of the organic molecule in the gaseous state, at 25° C. and constant pressure, of 157.00 ± 0.08 $Cal._{15}$ per mol." From the data given and also from other data, values are calculated for the heats of formation of all the normal paraffin hydrocarbons in the gaseous state at 0° and 298°K. The energies of the atomic linkages are discussed.

**The Solubility of Technical Alcohol and Benzene in Gasoline for Aero-Engine Fuel.** TSURUO ARAKI AND MASAMOTO NAKABAYASHI. *J. Soc. Chem. Ind., Japan* **37** (1934), Suppl. binding, pp. 310-11.

Solubility data were determined for 23 mixtures of gasoline and alcohol, 37 mixtures of alcohol and benzene, and 239 mixtures of gasoline, alcohol and benzene. The results are presented in the form of a ternary equilibrium diagram.

**The Raman Effect. XXXII. The Raman Spectra of Paraffins.** K. W. F. KOHLRAUSCH AND F. KOPPL. *Z. physik. Chem.* **B26** (1934) pp. 209-37.

The authors obtained Raman spectra for ethane, propane, butane, pentane, hexane, heptane, octane, nonane, decane, undecane, dodecane, cyclopropane, isobutane, isopentane, tetramethylmethane, heptyl chloride and heptyl bromide.

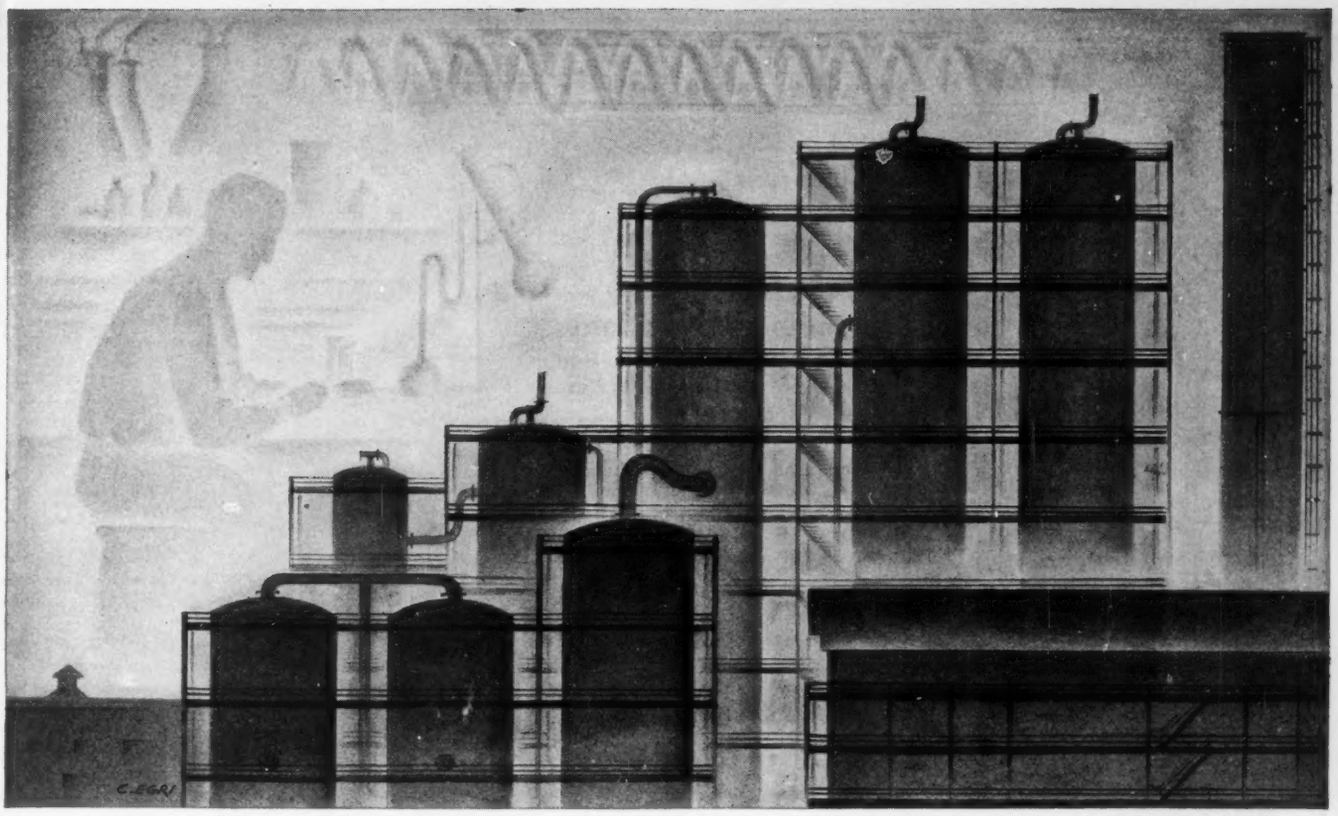
## Chemical Composition and Reactions

**The Mechanism of Formation of Methane and of Condensation Products by the Pyrolysis of Ethane, Ethylene, etc.** M. W. TRAVERS AND T. S. P. PEARCE. *Chem. & Ind.* **53** (1934) pp. 321 T—36 T.

The authors stress the point that no group of chemical reactions is of more importance, either scientifically or technically, than those involved in the thermal decomposition of hydrocarbons. The paper is divided into three sections dealing, respectively, with experiments with equilibrium mixtures of hydrocarbons, the determination of the equilibrium constant for the system ethane-ethylene-hydrogen, and experiments with pure ethane. The article is too detailed for brief review. However, it is shown that when a mixture of ethane, ethylene and hydrogen, initially in equilibrium proportions, is subjected to pyrolysis in the neighborhood of 600° C. and at pressures up to six atmospheres, the equilibrium relations between the concentrations of the components are not disturbed in spite of the fact that ethylene is being removed from the system in the formation of condensation products and of methane, and is simultaneously being regenerated from the ethane. The thermal reactions of pure ethane were studied in great detail and the results of these experiments are presented. The theory of free radicals in relation to the reactions of ethane is reviewed and criticized. They conclude that although the theory of radical formation may account for the primary decomposition of ethane and the primary hydrogenation of ethylene, it does not account for the formation of condensates or for the formation of methane, nor for the influence of methane in increasing the rate of formation of methane. The paper is a valuable detailed contribution to the knowledge of this general subject of hydrocarbon decomposition.

**Pyrolysis of Coal.** B. JUETTNER AND H. C. HOWARD. *Ind. Eng. Chem.* **26** (1934) pp. 1115-18.

In thermally decomposing coal many attempts have been made to obtain primary products of decomposition, because of the assumption that substances normally found in coal tar are formed by cracking primary into secondary products. However, in no case have the experimental conditions used by investigators met the theoretical requirements that a molecule resulting from the pyrolysis once it is in the gas phase shall have no collision with another molecule or with a surface hotter than that from which it has just originated, before condensation on a colder surface. To meet these requirements that insure that there shall be no secondary decomposition, it is necessary thermally to decompose the coal in a vacuum of the order of $10^{-3}$ mm., if the distance from the evaporating to the condensing surface is of the order of 1 to 10 cm. The present study of vacuum distillation has been under conditions meeting these requirements. The molecular still, in addition to serving as a useful means for purifying substances of moderate molecular weight, thus affords a satisfactory means of carrying out the controlled pyrolysis of large molecules and constitutes a new tool in the study of complex organic bodies. Even under the most favorable conditions, condensable products were not obtained from Pittsburgh bed coal until temperatures were reached such that gas evolution was considerable. Presumably, therefore, the products were the result of thermal decomposition. The maximum yield of condensable products was obtained by the distillation of finely ground coal at 525° C. and equaled 27%. Exhaustive step-wise decomposition gave markedly lower yields than rapid heating to the same maximum temperature. The



# INTEGRATED PROGRESS IS THE RESULT OF RESEARCH

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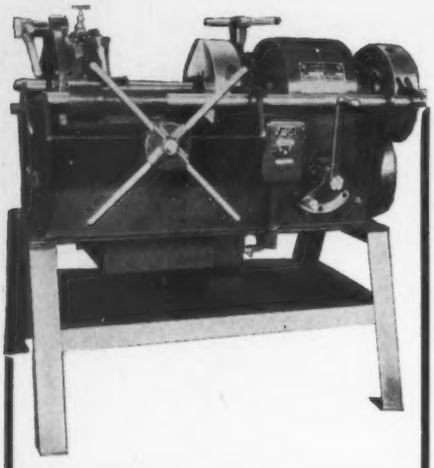

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usual increased hydrogen content of the gas at the close of a carbonization period was observed in the vacuum distillation. In this case it cannot be caused by secondary decomposition of methane, but must be the result of some change in the mode of decomposition of the coal itself. The condensable products from vacuum distillation are semi-solids and yellow to brown in color and contain relatively small amounts of volatile material.

## Manufacture: Processes and Plant

**The Heat Loss from a Smooth Vertical Plate in Oil with Natural Convection.** HANS H. LORENZ. *Z. tech. Physik* 15 (1934) pp. 362-6.

An apparatus for determining the heat loss from a smooth vertical plate in oil and through the action of natural convection is described. A method for determining the mean temperature of the oil is given. The results can be expressed in the form of the Nusselt number as a function of the Grashof and Prandtl numbers. These results are compared with existing data. The velocity of the oil and the expansion of the boundary layer next to the plate are discussed.

**Entrainment in a Bubble-Cap Distillation Column.** G. E. HOLBROOK AND E. M. BAKER. *Ind. Eng. Chem.* **26** (1934) pp. 1063-67.

The work of the authors was directed toward securing quantitative data on entrainment in a bubble-cap fractionating column. The variables studied were column vapor velocity, amount of reflux, plate spacing, slot vapor velocity and surface tension. The study was confined to a steam-water system. Entrainment was determined by continually introducing a salt solution on one plate and calculating the quantity of liquid that must have been mechanically carried to the plate above as entrainment in order to raise the salt concentration of the plate above to that found by analysis. The column used was 8 inches in diameter with movable plates and with a glass observation section. Each plate had two bubble-caps and the plates were fitted with telescopic down-pipes to permit change in liquid level. It was found that plate spacing and column vapor velocity were of substantially equal importance in determining the amount of entrainment. In general, doubling the column vapor velocity resulted in approximately a ten-fold increase in entrainment. However, the closer the column plates are, the greater is the effect of column vapor velocity. Cutting the plate spacing in half also results in an approximate ten-fold increase in entrainment. Quantity of reflux has only a moderate effect on entrainment. In one instance tripling the reflux resulted in a two-fold increase in entrainment. Entrainment is not sensitive to change in slot vapor velocity. Under one set of conditions increasing the slot velocity 2.4 times doubled the entrainment. Under another set of conditions this same increase in slot velocity actually decreased entrainment. Surface tension of the liquid affects the amount of entrainment, as would be expected. However, compared to other variables it is not important. A generalized correlation between surface tension and entrainment is not yet possible.

**Entrainment in Oil Absorbers.** F. A. ASHRAF, T. L. CUBBAGE, AND R. L. HUNTINGTON. *Ind. Eng. Chem.* **26** (1934) pp. 1068-72.

The authors briefly review previous work on entrainment. They then report data secured in the operation of two small laboratory columns and one semi-commercial tower. As regards plate spacing, they conclude that some entrainment occurs regardless of the distance between plates. This is probably occasioned by minute liquid droplets floating in the gas stream. At lesser spacing a large part of the entrainment results from the splashing of comparatively large drops. Entrainment increased substantially in a linear manner with depth of submergence. The rate of increase of entrainment with velocity is slow up to a certain point, but then increases very rapidly. This critical point is probably the velocity above which the jetting action and carrying of large droplets begins to control. The authors conclude that the various factors affecting the values of constants in equations that have been proposed will have to be investigated further before any general relationship can be developed.

**Diffusion of Vapors through Gas Films.** T. K. SHERWOOD AND E. R. GILLILAND. *Ind. Eng. Chem.* **26** (1934) pp. 1093-96.

The authors state that diffusion in gas films is one of the most important problems confronting the chemical engineer. This is true because diffusion rates determine the capacity of various types of equipment, and therefore the fixed charges on many industrial operations. The rate of interaction of a gas with a liquid or solid may be governed by the rate of a slow chemical reaction, or by the rate of diffusion through the liquid phase. In many of the most important operations, however, the rate depends upon diffusion through the gas phase. Typical cases are the absorption by liquids of soluble gases from mixtures with inert gases, the adsorption of gases by solid adsorbents, air drying of wet solids, the vaporization of water or other liquids into air as in humidification, the condensation of vapors from mixtures containing non-condensible gases, the evaporation of solvents as in the drying of lacquers, and the combustion of solids at high temperatures. The nature of a gas film is briefly discussed and the application of the Stefan-Maxwell equation to diffusion in gas films is explained. The results of experiment on rates of vaporization of various liquids into air are reviewed, and rules are given for estimating the diffusion rate of a vapor through a gas film on the basis of data on the diffusion rate for another vapor. The necessary calculations are illustrated by numerical examples. Derivations of algebraic equations connecting the absorption coefficients with the height of packing equivalent to one theoretical plate are given. The use of the concept of the H. E. T. T. in the design of packed towers for absorption is discouraged. The H. E. T. T. is dependent not only on those variables which affect the absorption coefficients, but also on additional effects of gas and liquid weight velocities and on the slope of the equilibrium curve Because of the effect of the latter variable the H. E. T. T. may be expected to vary throughout the apparatus with solute concentration.

**Phenolic Resin Bubble Caps in Recovery Plant.** G. W. CLARK. *Chem. & Met. Eng.* **41** (1934) pp. 542-3.

A recital of the difficulties encountered and cost involved in cleaning bubble-cap scrubbers with cast iron caps, these scrubbers being used in solvent recovery service and involving contact with water, alcohol, furfural and cresol. Micarta laminated phenolic resin caps were placed in service. After eight months of operation they were unchanged except for a fine deposit of rust that was readily removed by wiping. Micarta caps are recommended for service in boiling water, or alcohol, but not in boiling furfural or cresol. Other favorable applications include boiling esters, alcohol, paraffin, ketone, cold weak mineral acids, and weakly

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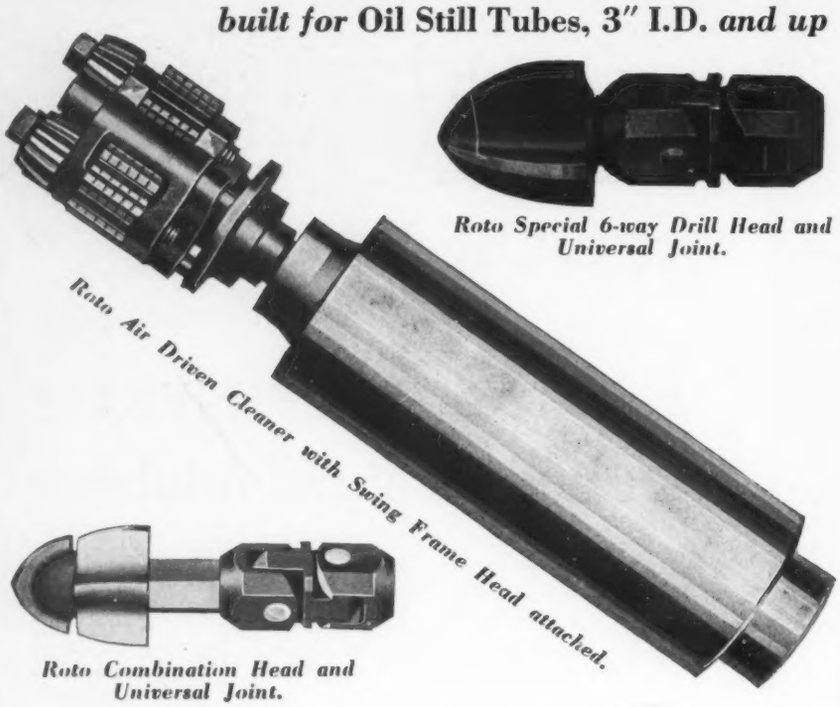

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alkaline liquids. They should not be used in strong alkalies nor in contact with oxidizing acids such as nitric and chromic.

**Applications of the Film Concept in Petroleum Refining.** C. C. MONRAD. *Ind. Eng. Chem.* **26** (1934) pp. 1087-93.

For several years there has been a growing appreciation of the fact that many industrial processes, although seemingly unrelated, depend upon the properties of thin films of material. In view of the wide application of the film concept, the author has reviewed some of the applications that have been made in petroleum refining and some others that are possible. The correlation of the unit processes by the film theory is first outlined. Its application to heat transfer, pressure drop, fractionation, and absorption are considered. The subject of evaporation in its relation to refinery losses is then discussed, as, for example, from tankage, separators, and loading facilities. An equation is developed for evaporation from large plane surfaces to flowing gases, based on heat transfer and diffusion data obtained by several investigators. Various possible miscellaneous applications of the film theory are briefly given.

**Materials of Chemical Engineering.** H. L. MAXWELL. *Chem. & Met. Eng.* **41** (1934) pp. 511-512.

The author discusses past and probable future trends in the development of the materials of chemical engineering. Three important factors must be considered in selecting materials for construction of process equipment: First, initial cost; second, potential life of equipment if continued in service; and third, probable life of the process. Among the materials briefly reviewed are the chrome steels, cast irons and alloy cast irons, organic plastics and surface coatings, and materials for high temperature and pressure.

**Materials of Construction for the Process Industries.** Numerous Authors. *Chem. & Met.* **41** (1934) pp. 513-34.

This review of materials of construction for the process industries includes fifty-five short articles covering more than sixty process industry products. Among the materials covered are acetic acid, acetic anhydrides, acetone, aluminum chloride, ammonia, bromines, calcium chloride, alcohol, caustic soda, glycerine, hydrochloric acid, nitric acid, materials and conditions encountered in petroleum refining, sodium hypochlorites, stearic acid, sodium sulphide, sulphuric acid.

**Chem. & Met. 1934-35 Directory of Materials.** Editorial Compilation. *Chem & Met. Eng.* **41** (1934) pp. 549-56.

This is a listing of metals, non-ferrous alloys, ferrous alloys, rubber products, glass and fused silica, glass-lined equipment, chemical stoneware, plastics, vulcanized fibers, carbons, asbestos, acid-proof brick and masonry, and cementing materials. The manufacturers of the various materials are given, as well as the general composition of the material.

**Cements for Corrosion, Heat, and Solvent Resistance.** T. R. OLIVE. *Chem. & Met. Eng.* **41** (1934) pp. 537-40.

The materials used as cement or lutes with which the chemical engineer is primarily concerned are the ones used for jointing, heat or corrosion resistant masonry and stoneware shapes, for making liquid- or gas-tight joints between metals and non-metals, for making up pipe threads and gaskets, and for producing resistance surfaces on equipment in contact with deteriorating substances. Materials for producing relatively permanent joints are referred to as cements. Those for joints of a more temporary character are usually called lutes. Silicate

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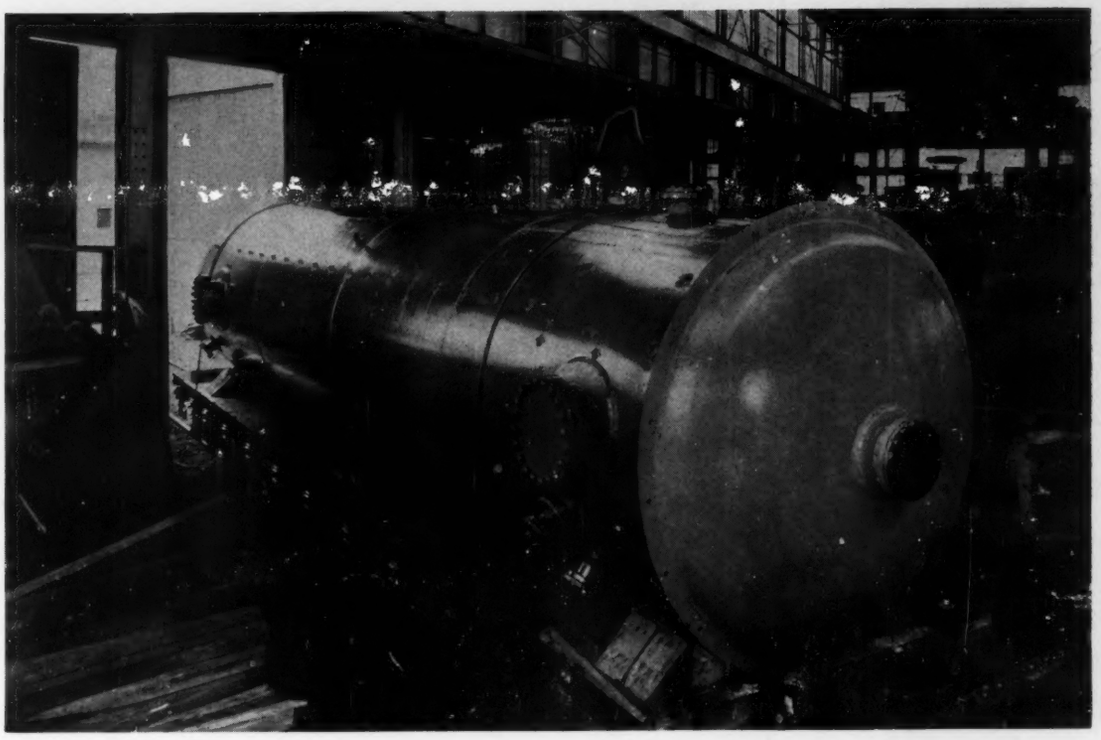

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cements of various types are discussed. Formulas are given for several organic binder cements and lutes, including those containing asphalt, pitches, gilsonite, linseed oil, rubber, and litharge and glycerine. The making of a sulphur base cement is outlined. The composition of a satisfactory rust joint or iron cement is given. Types of cement suitable for strong and weak acids, ammonia, gas, hydrocarbons, for high temperature, for steam, and for water are briefly outlined. Proper methods of using and applying cement are discussed.

**Vapor-Phase Clay Treatment of Cracked Gasoline.** H. M. STEININGER. *Ind. Eng. Chem.* **26** (1934) pp. 1039-44.

The principal objects in treating cracked gasoline are to secure color removal, color stability, and oxidation stability. Minor objects are odor removal, the securing of copper corrosion, and lowering of sulphur content. High yields can be obtained from clay treatment when using the initial color of the treated product as a criterion. Yields of 5000 to 6000 barrels of acceptable color stability gasoline per ton of clay can be obtained when treating distillates of the type available at this plant and under the conditions there employed. Early work on clay treatment was conducted at substantially atmospheric pressure, but it has been found that higher pressure and temperature with increased contact time results in improved color stabilty. Data are presented on dark and sunlight storage for products obtained in various yields from clay. Data are also presented on oxidation stability in the form of the relation of induction periods to clay yields. It is the opinion of the author that since gasoline of good initial color can be obtained up to high yields from clay, at which yields the color stability may not be as high as desirable, the use of butyl or amyl amines offers a means of securing improved color stability. Data are presented showing the effects of amyl amines on color stability.

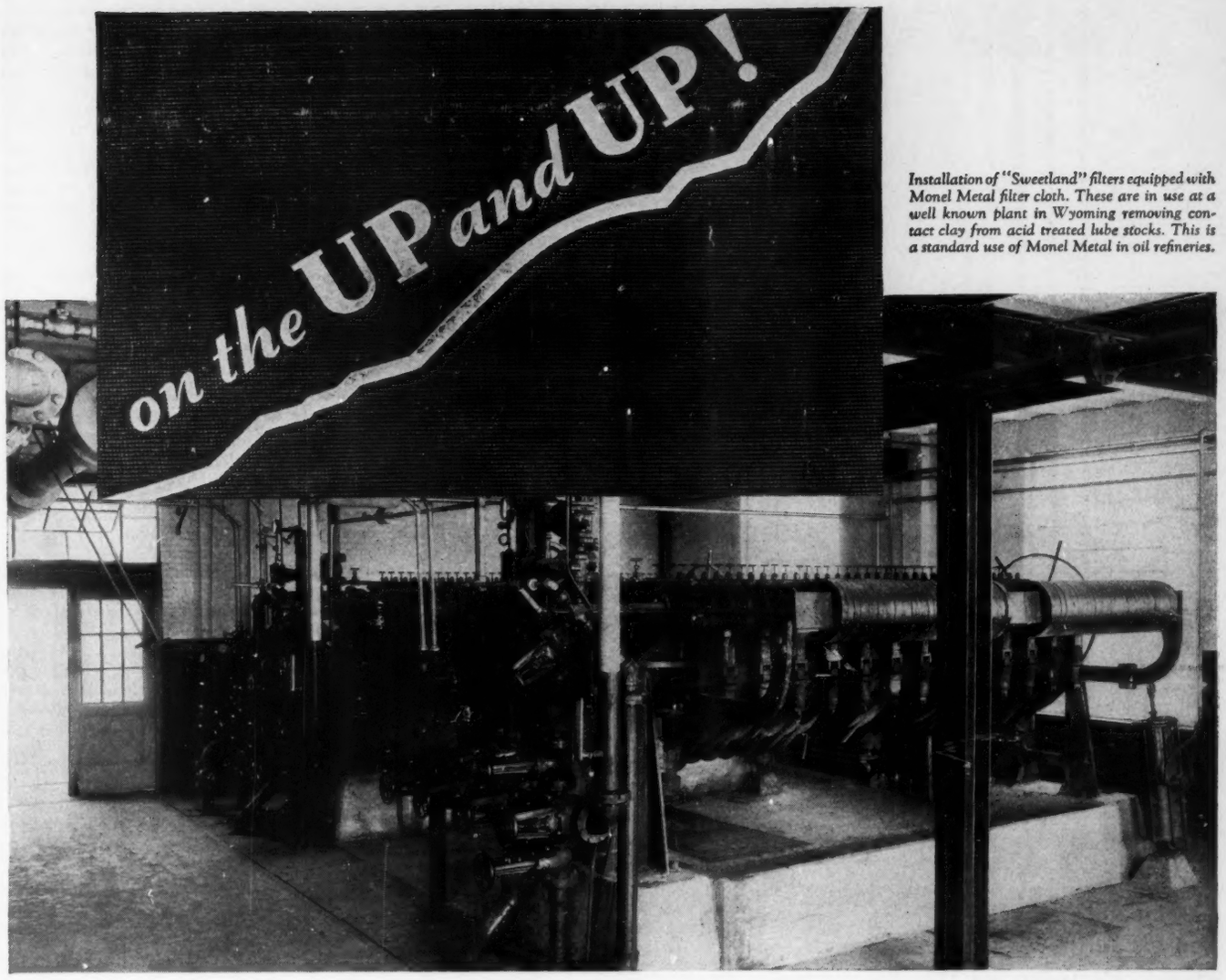
**Lubricating Oils from Ethylene.** R. G. ATKINSON AND H. H. STORCH. *Ind. Eng. Chem.* **26** (1934) pp. 1120-22.

It has been shown by other authors that the viscosity index of an oil produced by the polymerization of olefins increases proportionally to the length of the straight-chain carbon atom chain in the starting material. It was therefore deemed advisable to investigate the possibility of obtaining a good lubricant by first polymerizing ethylene to a liquid of low molecular weight, and then treating this liquid with aluminum chloride to secure a viscous liquid. The experiments indicate that it should be possible to produce a good light lubricant from the lower members of the olefin series by a two-stage process. The apparatus used in the work is described and the data secured are presented in tabular and graphical form.

## Products: Properties and Utilization

**Equilibrium Volatility of Motor Fuels from the Standpoint of Their Use in Internal-Combustion Engines.** OSCAR C. BRIDGEMAN. *J. Research Natl. Bur. Standards* **13** (1934) pp. 53-109.

The paper is a valuable discussion and presentation of data on the relationship between fuel characteristics and engine performance, particularly as regards equilibrium volatility. Thirty-eight motor fuels were studied. It was shown that a definite relationship exists between the easily made A.S.T.M. distillation curve and the more laboriously constructed equilibrium air-vapor evaporation. A refinite relationship was found to exist between the bubble point and the 10% evaporation point on the A.S.T.M. curve and between the dew point and the 90%

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evaporation point on the A.S.T.M. curve. Pressure in an engine manifold is usually much less than one atmosphere, but no volatility data have been obtained for pressures lower than atmospheric. However, it is possible to compute these data at any reduced pressure from the normal atmospheric values, and a method is given for making such calculations. Knowledge of volatility data formed the basis for investigation of the effects of fuel volatility on engine performance and operation, but until more definite information is available on manifold equilibrium vaporization, progress will be slow.

**The Possible Consequences of the Use of Fuels of High Anti-Knock Value in Motors.** C. BONNIER AND MOYNOT. *Ann. combustibles liquides* **9** (1934) pp. 481-8.

The use of motor fuels of high octane number disturbs the heat balance of an engine in the sense that more heat is lost to the exhaust and less to the cylinder walls. This may result in trouble with the exhaust valve and requires that more attention be paid to valve cooling. Experiments were made using leaded fuels, and benzole and alcohol blends. In the zone of audible detonation exhaust valve temperatures increased with octane number, increase being greater the higher the compression ratio. Outside the region of audible detonation the temperature of the exhaust gases remained practically constant at given compression ratio and mixture strength, regardless of the anti-knock value. Exhaust gas temperature decreases with increasing leanness of the fuel mixture. The temperature also decreases as the compression ratio is increased, especially if the anti-knock value of the fuel is low.

**Gum Formation in Fuels. Its Prevention by the Use of Inhibitors.** W. H. HOFFERT. *Chaleur & Ind.* **15** (1934) No. 167, pp. 389-401.

The author discusses the effects of gum formation, the determination of actual and potential gum, the prevention of gum formation by means of inhibitors, and the application of inhibitors in the production of cracked gasolines, benzenes, and gasolines from the hydrogenation of coals and tars. A bibliography is appended.

**Lubricating Grease.** H. S. GARLICK. *Jour. Inst. Pet. Tech.* **20** (1934) pp. 829-83.

The paper is a discussion of lubricating greases, methods of manufacture, materials and equipment used, and properties and purposes of the various types of greases. Grease-making has been a highly developed art. Recently increased speed and bearing pressures have given rise to conditions requiring greatly improved greases, with the result that the research study of greases has been greatly stimulated. The author classifies greases as lime base greases of the cup and sett types, soda base greases, lead base greases, aluminum base greases, and miscellaneous and special greases. The manufacture of each of these and the materials used in making each is discussed. The properties and uses of each type of grease are given. In the last ten pages of the article the author discusses the characteristics of greases and the methods of testing greases. In conclusion the author notes that there are opportunities for research in every direction in connection with grease, since less attention has been paid to this subject than to any other branch of petroleum technology. Very little is known with regard to the actual merit of soaps from different fats, methods of manufacture are capable of material improvement, and the use of colloids and emulsifying mills is well worthy of study. New types of soap and new gelling agents are available and should be studied. Ten pages of discussion by various members of the Institution follow the conclusion of the author's paper.

# THE MONTH IN REVIEW

## Gasoline Quota For December

THE allowed production of gasoline by refinery districts (including the production of straight-run and cracked gasoline and the natural gasoline blended therewith, either at refineries or terminals) has been determined, in accordance with Section 3, Article IV of the Code, to be, for December, 1934, as follows:

| District— | Amount (42-gal. bbls.) |
|---|---|
| 1. East Coast | 5,890,000 |
| 2. Appalachian | 1,510,000 |
| 3. Indiana-Illinois-Kentucky | 5,200,000 |
| 4. Oklahoma-Kansas-Missouri | 4,282,000 |
| 5. Texas: | |
| (a) Inland Texas | 2,216,000 |
| (b) Texas Gulf Coast | 6,167,000 |
| (c) East Texas | 700,000 |
| 6. Louisiana-Arkansas: | |
| (a) Louisiana Gulf Coast including Alabama | 1,115,000 |
| (b) North Louisiana-Arkansas including Mississippi | 661,000 |
| 7. Rocky Mountain | 702,000 |
| 8. California | 4,517,000 |
| Total United States | 32,960,000 |

## Symposium on Distillation

THE program of the Symposium on Distillation of the Division of Engineering Chemistry of the American Chemical Society, to be held at Cambridge, Massachusetts, displays a breadth of information on the chemical engineering design of rectification equipment, balanced with experimental studies of two interesting three-component systems. The authors' activities are well distributed between academic and industrial pursuits, so that a lively discussion of design procedure is promised. Ample time is allowed to make this discussion valuable and complete. The symposium will be held in the Eastman Building at the Massachusetts Institute of Technology on Friday and Saturday, December 28 and 29, enabling a large attendance by those who can take advantage of the Christmas holidays to visit Cambridge. There will be informal dinner gatherings Friday evening and Saturday noon. The program follows:

G. G. Brown—Methods of Design for Petroleum Fractionating Columns.

C. C. Furnas—The Distillation of the System Normal Butyl Alcohol-Butyl Acetate-Water.

T. K. Sherwood and F. J. Jenny—Entrainment in Bubble Cap Columns.

E. R. Gilliland—A New Design Calculation for Multicomponent Rectification.

H. F. Johnstone and D. B. Keyes—Distillation of a Three-Component System $NH_3$—$SO_2H_2O$.

E. W. Thiele—The Graphical Method of Ponchon and Its Application to Distillation and Absorption.

T. H. Chilton and A. P. Colburn—A Convenient Design and Correlation Method for Distillation and Absorption in Packed Columns.

W. A. Peters, Jr.—The Importance of Theoretical Calculations in Distillation Problems.

James S. Carey—Distillation Operations in Modern Petroleum Refining.

## Interesting Program for C. N. G. A. December Meet

THE latest developments in the manufacture of synthetic rubber, how to get the most mileage out of auto tires, and a variety of other topics of popular interest regarding rubber and its uses were discussed by H. M. Stilley, manager of the quality control department of the Los Angeles branch of Firestone Tire and Rubber Company, at the December meeting of the California Natural Gasoline Association.

A principal source of raw material used in the manufacture of the new synthetic rubber, Duprene, as well as a large user of rubber, the petroleum industry is vitally interested in the advancements in rubber processing. Mr. Stilley explained not only the many interesting uses for Duprene, but also the latest improvements in tire manufacture. Starting with the growing of rubber, told how the raw rubber is prepared; the coagulation, sheeting and bailing processes; and the final stage of rubber application to tire manufacture. He discussed the manufacture of tires for racing automobiles, as well as those for trucks and passenger cars, and the most effective air pressures to carry and how to get the most mileage. The talk was supplemented by motion pictures of the Firestone exhibit at the Century of Progress.

On the same program, C. D. Gard, gas engineer for Union Oil Company, described the Bassler meter for the accurate measurement of large volumes of gasoline or oil. Using information based on practical field experience with the Bassler meter, Mr. Gard discussed its calibration, operation, and maintenance. Because of the possibility of improving vastly over the old methods of gauging natural gasoline shipments, the meter is rapidly creating wide attention. While new to the natural gasoline industry, it is in use all over the world for heavy oil measurement. In addition to Union Oil Company's work The Texas Company has conducted a similar investigation at Signal Hill. T. R. Beauchamp, general plant foreman of The Texas Company gasoline division, participated in the discussion with interesting data on their experiences. Mr. Bassler, inventor of the meter, was present for the discussion.

# Natural Gasoline Association Has New Research Program

ANOTHER research program of general interest to both motor fuel and automobile manufacturers is being initiated by the Natural Gasoline Association of America, according to a recent announcement of D. C. Williams, Continental Oil Company, president of the organization.

Under the direction of Dr. George G. Brown, director of chemical engineering at the University of Michigan and nationally known authority on motor fuels, the project will cover a long series of practical experiments to demonstrate the actual value of high volatility motor fuels in standard motor cars having their intake manifolds modified to function at temperatures sufficiently low to handle this type of fuel.

It is estimated that the complete series of tests will cover a period of about two years during which time both chassis dynamometer and road tests will be made with several makes of cars under all types of road and weather conditions. All of the research facilities of the University of Michigan Engineering Research Laboratories will be made available for use in the project and exhaustive tests along several lines of technical reasoning are included in the plans.

Funds for starting the project have been raised largely within the membership of the association itself though certain other interests are being asked to contribute since all successful results will be equally beneficial to motor fuel manufacturers generally as well as to the automotive industry. First tests started early in November and will be continued throughout the winter as the first cold weather phase of the project.

The new research program was prompted by conclusions drawn from experi-

ments made by Dr. Brown last year on the potential value of motor fuel as determined by octane number and total volatility. As consulting engineer of the association, Dr. Brown reported his findings in a paper on the subject[1] before the Thirteenth Annual Convention of the association last May. His work agreed with and closely paralleled that of Neil MacCoul,[2] director of mechanical research, The Texas Company, who conducted similar tests for his company with modern motor cars and using gasolines ranging in end points from 312° F. to 432° F.

Dr. Brown indicated in his report that the modern automotive engine rarely made full use of the potential value of present motor fuels as indicated by their octane ratings. The reason given was that the engines were not designed to take full advantage of the actual value offered. He said that somewhat the same condition exists in regard to volatility, in that few if any engines really use the full volatility of standard grade fuels. It is generally conceded, however, that all engines make full use of starting volatility as indicated by the lower end of the A.S.T.M. distillation just as they use the warming-up volatility evident in low 50 percent points. "Therefore, lower end or 'partial' volatility of motor fuel is always effective in controlling starting and warming up, or acceleration, on all cars and represents not simply potential value but actual service value in all cases."

"Upper end of 'total' volatility, as represented by low 90 percent points, indicates the ability of the fuel to deliver a substantially dry mixture at low manifold temperatures. But no advantage is obtained by the use of fuels of this type unless the mixture temperature is decreased, just as there is no advantage in the use of fuels of high octane number unless the compression ratio is increased."

In view of the conclusions reached by both these outstanding research engineers through actual tests with various motors and fuels, it is reasonable to suppose that a research program which has as its purpose the practical proof of the advantage of volatility where proper fuel induction systems are used, might very well result in changes in engine design as well as in general fuel specifications. The proof in this particular case is to take the form of experiments in changing or modifying the fuel intake system on different makes of cars so that the engines of those cars may take full advantage of the actual value of the more volatile fuels under actual driving conditions in all weather.

[1] The Potential Value of Motor Fuel as Determined by Octane Number and Total Volatility, by Dr. George Granger Brown and Clair A. Marshall, University of Michigan—Proceedings of the Thirteenth Annual Convention of the Natural Gasoline Association of America, May, 1934, page 82.

[2] Effect of Gasoline Volatility on Engine Economy, by Neil MacCoull—S.A.E. Journal, Vol. 33, No. 5, November, 1933, page 363.

Such results would be favorable to all parties concerned including the motoring public. Natural gasoline manufacturers could reasonably expect a somewhat wider market for their product, many refiners would have a place to put their excess butane, engine designers could boost compression ratios and build smaller and more economical engines and the car owner would have a more economical and more flexible transportation unit.

## American Petroleum Institute Elections

AXTELL J. BYLES was re-elected president of the American Petroleum Institute, to serve for 1935, by its board of directors, November 14, during the annual meeting at Dallas, Texas. Byles has served as president of the institute since the Tulsa mid-year meeting, in 1933, when he was elected to take the place made vacant through the resignation of C. B. Ames when he became chairman of the board of The Texas Company. Byles left the presidency of the Tidewater Associated Oil Company to head the institute activities. He is a member of the Planning and Coordination Committee at Washington. The election of officials included the return of the entire New York headquarters staff.

Other elections at the same time were as follows:

Vice president at large, K. R. Kingsbury, president, Standard Oil Company of California, San Francisco.

Vice president for production, George A. Hill, Jr., president, Houston Oil Company of Texas, Houston.

Vice president for refining, W. G. Skelly, president, Skelly Oil Company, Tulsa.

Vice president for marketing, C. E. Arnott, president, Socony-Vacuum Oil Company, New York, re-elected.

Executive vice president, W. R. Boyd, Jr., New York, re-elected. Treasurer, Frank Phillips, president, Phillips Petroleum Company, Bartlesville, Oklahoma.

Secretary and assistant treasurer, Lacy Walker, New York, re-elected.

The directors reappointed the executive committee, which includes the newly elected officials and the following:

C. B. Ames, chairman of the board, The Texas Company, New York.

W. C. Teagle, president, Standard Oil Company of New Jersey, New York.

H. F. Sinclair, chairman of the board, Consolidated Oil Corporation, New York.

E. G. Seubert, president, Standard Oil Company of Indiana, Chicago.

J. C. Van Eck, president, Shell Union Oil Corporation, New York.

F. A. Leovy, vice president, Gulf Oil Corpration, Pittsburgh.

J. Howard Pew, president, Sun Oil Company, Philadelphia.

The board of directors re-elected the following directors-at-large: T. H. Barton, Lion Oil & Refining Co., El Dorado, Arkansas; E. R. Brown, Magnolia Petroleum Company, Dallas, Texas; F. S. Fales, Standard Oil Company (New York), New York; J. C. Van Eck, Shell Union Oil Corporation, New York; A. L. Beaty, Phillips Petroleum Company, New York; R. G. A. Van der Woude, Shell Union Oil Corporation, New York; H. R. Gallagher, Consolidated Oil Corporation, New York; B. F. Harris, Oil Well Supply Company, Pittsburgh, Pennsylvania; H. L. Hunt, H. L. Hunt, Inc., Tyler, Texas, and Ralph B. Lloyd, Oil Producers Sales Agency, Los Angeles, California.

The board created four new directorships-at-large, electing the following: R. L. Wheelock, Corsicana, Texas; George A. Hill, Houston Oil Company, Houston, Texas; John M. Lovejoy, Seaboard Oil Company, New York, and W. S. Farish, Standard Oil Company of New Jersey, New York. Mr. Farish was transferred to the directorship-at-large group from his former position as director representing the Central United States Production Group, upon recommendation of the board of councillors.

The executive committee of the institute created a new office in the institute's staff. It is that of assistant secretary of the institute, and the first appointee is "Dr." J. S. Cooke, who has been secretary to Executive Vice President W. R. Boyd, Jr.

The annual meeting of the institute in 1935 will be held in the fall in Los Angeles. The mid-year meeting next year will be at Tulsa.

## Information on Tests of Lube Oils

THE Government Printing Office has issued a pamphlet entitled "General Information for Refiners of Petroleum," regarding the Tests of Lubricating oils at the Engineering Experiment Station, Annapolis, Md. This is a revision of the Bureau of Engineering Pamphlet, same title, 1932 edition, and is subject to change or modification as found desirable. Copies may be obtained at the price of five cents each from the Government Printing Office:

Federal Specification VV-L-751, "Lubricant; Chain and Wire-Rope," superseding part of F. S. No. 2d, October 21, 1927.

Federal Specification VV-O-261, "Oil; Cutting, Soluble," superseding part of F. S. No. 2d, October 21, 1927.

## Italian Control May Affect Foreign Companies

SOME aspects of Italy's new petroleum regime probably will call for changes in operating policies of foreign corporations in that country.

While it is not necessarily true that the Italian government is definitely seeking to weaken the position of private enterprise in the Italian oil industry, it is true that the government is strengthening its own position in the Italian market.

According to Signor Asquini, Italy, operating through the A. G. I. P., the government owned and controlled oil corporation for producing, refining and marketing, assures itself of ability to compete successfully with all international companies.

Under Italy's new petroleum regime, importation of crude petroleum and derived petroleum is authorized only after the grant of a license, said license having a duration of three years for the finished products and 20 years for crude. Permission of the state must be obtained for construction of new refineries and for the enlargement of existing installations.

The regime provides that the refiners must accumulate a certain amount of stocks of crude petroleum and advise the minister of corporations each month concerning the amount of these stocks on hand. In this connection, the Italian government has priority, or first call, on all stocks of crude pertoleum held in Italy.

## Standard Oil Development Personnel Changes

WITH steadily increasing contacts and closer cooperation between the sales department and the Standard Oil Development Company a re-alignment of responsibilties in the latter organization became necessary, according to recent announcement in The Lamp, official organ of Standard Oil Company of New Jersey.

For the past year or so R. T. Haslam, vice president and general manager of the company, has been working closely with the sales department, particularly in the development of its lubrication division, leaving much of the active supervision of development company work upon R. P. Russell, general manager of the company's development division and of the Hydro Engineering and Chemical Company. Mr. Russell has now been elected vice president and general manager of Standard Oil Development Company. Dr. Haslam, while remaining vice president and director of the company, will be free to devote more of his time to sales.

W. R. Carlisle, vice president of Standard-I. G. Company and Dr. W. V. Hanks, head of the technical information unit of the development company and secretary of the technical committee, have sailed for London where they will be engaged in development of company activities in Europe. W. Carl Winning comes over from Bayway to take over Dr. Hanks' work in New York.

The legal and patent departments of the company have been consolidated under the direction of W. E. Currie, vice president, and R. H. Dickson has been transferred to the new department. Dr. G. M. Maverick, manager of research and development activities at Bayway, has been transferred to the New York office to take over supervision of many of the general technical activities formerly coming under Mr. Russell.

To coordinate development work carried out by Standard Oil of Louisiana for the development company's account, E. V. Murphree, formerly director of research and development at Baton Rouge, has been transferred to the New York office. D. G. Tompkins comes to "26" from Bayway and will be in charge of the general business and accounting office.

## Revisions Proposed for Petroleum Standards

IN line with its policy of keeping Methods of Testing Petroleum Products and Lubricants current with technical developments, the committee in charge of this project proposed for publication as tentative revisions certain minor changes in the text of the following standards:

Dilution of Crankcase Oils—Z11.29-1933 (A. S. T. M. D 322-33)

Distillation of Gasoline, Naptha, Kerosene and Similar Petroleum Products—Z11.10-1930 (A. S. T. M. D 86-30)

Precipitation Number of Lubricating Oils—Z11.30-1933 (A. S. T. M. D 91-33)

Water and Sediment in Petroleum Products by Means of Centrifuge—Z11.8-1930 (A. S. T. M. D 96-30)

The changes proposed will stand as tentative revisions for at least a year before being considered for possible incorporation into the test methods. Copies of these proposed revisions may be obtained from the American Society for Testing Materials, 260 South Broad Street, Philadelphia.

# Progress of Safety Work Shown by API Review

WORK done by oil companies during recent years has resulted in making the oil industry a leader in accident prevention. Since 1927, when the accident experience of petroleum was 18 percent worse than the average for all industries, constructive efforts of oil companies have improved the accident situation until the records for 1933 show an accident experience 12 percent better than the average for all industry. This constructive work has not only resulted in a great saving in injury costs to companies, but has saved workers in the industry much in suffering and loss of wages.

Each year an increasing number of companies have shown their interest in accident prevention by keeping accident records, and in turn, reporting their accident experiences to the American Petroleum Institute's Department of Accident Prevention for its "Annual Summary of Injuries in the Petroleum Industry." For 1933, 128 companies reported records covering 274,294 workers, computed according to N. R. A. working schedules. One man out of each 36 was injured so severely that it was necessary for him to lose time of one day or more from the job, as compared to one injury of a like nature in each group of 11 workers in 1927.

The Institute's Committees on accident prevention and its department of accident prevention are for the purpose of assisting oil companies with their problems on accident prevention and the promotion of their programs. Oil companies are urged to make every possible use of these facilities.

An "All Department" award is made to the company operating in the five major departments of the industry, namely, refining, marketing, production, natural gasoline and pipe line. This award is based on the least number of disabling injuries to each one million man hours worked. "Department Awards" are made to the companies operating in any of the five foregoing departments based on the lowest accident frequency rate. These awards are divided into two classifications, based on the number of men employed. An award is made to the marine department operating a deep sea fleet with the lowest accident frequency rate.

American Petroleum Institute Accident Prevention Certificates for 1933 are awarded as follows: Standard Oil Company (Indiana) and subsidiary companies received the All Department award; department of refining, Vacuum Oil Company, Inc., and Lincoln Oil Refining Company; marketing department, Standard Oil Company (Indiana) and Waggoner Refining Company, Inc.; production department, Continental Oil

Company and Chanslor-Canfield Midway Oil Company; natural gasoline department, Lone Star Gasoline Company and Shell Oil Company of California; pipe line department, Stanolind Pipe Line Company and Ajax Pipe Line Company; and marine department, The Texas Company.

In making the All Department Award to Standard Oil Company (Indiana) the accident experience of the departments in Standard Oil Company (Indiana), Stanolind Oil & Gas Company and Standard Pipe Line Company were taken into consideration. In the accident experience of 128 companies for 1933, their department ranking was—refining department, second place; marketing department, first place; production department, second place; natural gasoline department, fifth place, and pipe line department, first place. The exceptionally low accident severity rate of seven tenths of one day lost time for each 1000 hours worked as compared with one and nine tenths days for the industry.

## Reducing Evaporation Losses

RECOGNIZING evaporation of crude petroleum and gasoline as one of the most important sources of surface loss to the petroleum industry, the United States Bureau of Mines, Department of the Interior, has published a comprehensive report on applied methods and equipment for reducing evaporation losses of petroleum and gasoline. This bulletin by Ludwig Schmidt represents the findings of a detailed study extending over a period of years. It deals with evaporation losses on producing leases, in the transportation and storage of crude oil, and with evaporation losses of gasoline.

The bulletin is prefaced with a section on the theory of evaporation, discussed in simple language, and an outline is given of methods for determining the amount and rate of evaporation of crude petroleum and its products.

Bulletin 379, "Applied Methods and Equipment for Reducing Evaporation Losses of Petroleum and Gasoline," by Ludwig Schmidt, is now on sale by the Superintendent of Documents, Government Printing Office, Washington, D. C., price 20 cents.

## Foreigners to Share in Manchukuo's Oil Business

FOREIGN oil companies that have been operating in Manchukuo will be allowed by the government to participate in wholesale agencies on the basis of their respective shares of current business in Manchukuo, according to an announcement of the oil monopoly program from Hsinking.

With explanatory comment, the monopoly board announced the corporation representing Standard Oil Company of New Jersey and Socony-Vacuum Corporation will be allowed 35 shares in the monopoly; Asiatic Petroleum Company will be allowed 25 shares; The Texas Company, 20 shares; Soviet companies, 10 shares, and Japanese companies, 10 shares.

Administration of the oil control has created 10 districts, each of which will have a wholesale agency. One hundred shares in each agency will be distributed among foreign companies in the proportions outlined above.

While the foregoing applies to wholesale agencies, plans of the monopoly call for the eventual creation of retail agencies to buy and sell oil at prices specified by Manchuria Oil Company.

## Testing of Lean Absorption Oil

FILLING a long felt need for an exhaustive laboratory manual on the testing of absorption oil, the California Natural Gasoline Association announces the publication of Bulletin No. TS-343, Tentative Standard Procedure for Testing Lean Absorption Oil. It is the product of two years of intensive study by the C. N. G. A. Committee on Absorption Oil Testing, under the chairmanship of H. J. Multer of Union Oil Company.

Where formerly the essential plant tests on absorption oil were limited to gravity and simple distillation, the present day complexity of natural gasoline and vapor recovery gasoline manufacture has imposed specific test requirements on the chemist which are far more precise. Absorption calculations, lean oil reclamation, better still efficiencies, improved heat exchange, and greater plant capacities have all contributed to create the necessity for a treatise such as has been prepared.

Starting with an introductory section describing the scope and limitations of the work, the 72-page bulletin specifically takes up such tests as: A.P.I. gravity; Engler and Hempel distillations; vapor pressure; molecular weight; viscosity; gum content; water and sediment; acid and alkali shrinkage; and demulsibility.

Arranged in a form for quick reference, the test procedures are complete and well supplemented with remarks to assist in the interpretation of results. Essential equipment specifications are illustrated. Of particular interest is the table of gum contents for use in estimating when an oil should be put through the reclamation still.

Copies of Bulletin No. 343 are available at 25 cents each, postpaid, through the C. N. G. A. Secretary, 1217 Associated Realty Building, Los Angeles, California.

## California Association Nominations Announced

NOMINATIONS for the 1935 board of directors of the California Oil and Gas Association have been completed by the nominating committee, as follows: President C. S. Jones, vice president, Rio Grande Oil Company; Vice President Ralph B. Lloyd, president, Lloyd Corporation; Vice President L. P. St. Clair, president Union Oil Company of California; Treasurer H. L. Westbrook, vice president Belridge Oil Company; Sydney Belither, president Shell Oil Company; R. A. Broomfield, president Barnsdall Oil Company of California; R. E. Collom, vice president Continental Oil Company; J. A. Crawford, president Republic Supply Company of California; D. S. Faulkner, vice president National Supply Company of California; E. B. Gilmore, president Gilmore Oil Company; Wm. F. Humphrey, president Associated Oil Company; K. R. Kingsbury, president Standard Oil Company of California; W. C. McDuffie, receiver Richfield Oil Company of California; Alexander B. Macbeth, president Southern California Gas Company; A. C. Mattei, executive vice president Honolulu Oil Corporation, Ltd.; S. B. Mosher, president Signal Oil & Gas Company; C. E. Olmsted, vice president The Texas Company; W. B. Pyron, vice president Western Gulf Oil Company; William Reinhardt, manager Kettleman North Dome Association; F. C. Ripley, manager Chanslor-Canfield Midway Oil Company; A. L. Weil, president General Petroleum Corporation of California.

The annual election will be held on December 19, each individual firm, or corporation holding membership in the association having one vote.

## Production of Crude Oil for December

A DECREASE of 33,300 barrels daily in the national allowable production of crude oil for December was approved in an order signed by Secretary of the Interior Harold L. Ickes, the Oil Administrator.

Changes in state totals for December as compared with November follow: Arkansas 29,000, down 1000; California 456,800, down 5200; Colorado 3000, no change; Illinois 11,700, down 300; Indiana 2100, down 100; Kansas 123,900 down 1100; Kentucky 11,700, up 200; Louisiana 94,000, up 4000; Michigan 27,900, down 1100; Montana 8000, down 500; New Mexico 45,900, down 1100; New York 10,000, no change; Ohio 11,500, down 500; Oklahoma 451,600, down 7700; Pennsylvania 35,000, down 2200; Texas 941,300, down 16,000; West Virginia 11,000, down 100; Wyoming 32,600, down 600.

## Final Natural Gasoline Statistics for 1933

PRODUCTION of natural gasoline continued to decline in 1933 when the total output was 1,420,000,000 gallons, the lowest figure since 1926 and a decrease of seven percent from 1932, according to statistics compiled by the United States Bureau of Mines, Department of the Interior. This decrease resulted solely from a decline in the average yield of from 1.02 gallons per thousand cubic feet of gas treated in 1932 to .92 gallon in 1933.

Until recent years there was considerable relationship between the production of natural gasoline and that of crude oil as much of the gas utilized at natural gasoline plants is produced in conjunction with crude oil. However, the output of natural gasoline in recent years has declined irrespective of the trend of crude oil production; for example, in 1933, the production of crude oil increased 15 percent but the output of natural gasoline decreased seven percent. This significant development has resulted from a number of causes, chief of which are, first, the curtailment in supply of gas from flush fields as the result of proration; second, the effect of the discovery of the East Texas field, an important factor in oil production but, because of its low gas-oil ratio, of minor importance in natural gasoline production; third, the rapid increase in the quantity of low-yield dry gas processed in the Panhandle as an aftermath of the passage of laws permitting stripping; and, fourth, and most important of all, the loss in yield due to progressively high stabilization.

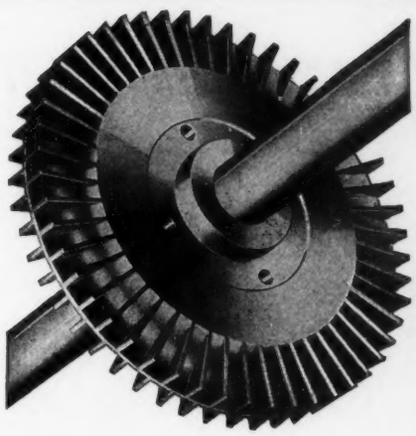
The concentration of the natural gasoline industry in fewer hands was continued in 1933 when there were 291 operators and 779 plants, compared with 302 operators and 830 plants in 1932. According to a biennial survey just completed, the total capacity of all plants on January 1, 1934, was 10,060,000 gallons daily, compared with a capacity of 11,387,000 gallons at the beginning of 1932. The elimination of the smaller and weaker units of the industry in recent years has resulted mainly from a steady decline in prices. However, in 1933 the average selling price increased, and the continued elimination of the uneconomic plants can probably be ascribed to the fact that the gain in prices was too small to allow the marginal operators to remain in business.

The relative rank of the principal natural-gasoline producing States in 1933 was much the same as in 1932 except that Texas, which had been third, replaced Oklahoma in second place. Production in California declined materially in 1933 but that State retained its rank as the leading producer.

The marketing of natural gasoline in the last decade has become increasingly difficult due to a growing indifference of the refiners with cracking plants. It has been a buyers' market and prices have suffered in consequence. In 1933 the inception of Q contracts improved the refinery market for natural gasoline so as to increase volatility ,with the result that direct sales of highly stabilized natural gasoline to consumers fell off. Stocks of natural gasoline showed a small increase during the year, totaling 139,052,000 gallons on December 31, 1933.

Prices of natural gasoline in the first half of 1933 reaches the lowest levels in the history of the industry. The price of 26-70 natural gasoline on January 1 was about 2.5 cents per gallon but by June 1 this price had fallen to one cent or a shade lower. Higher quotations for crude oil and gasoline were reflected in natural gasoline prices which improved during the summer months to over five cents per gallon.


*Westco's only moving part. This turbine-type Impeller enables Westco to produce multi-stage performance in only single-stage construction.* →



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Furthermore, these modern pumps supply an ideal, non-pulsating feed to high pressure stabilizers which increases the efficiency of the columns by eliminating overload and underload of the stabilizer trays. Westcos are favorites throughout the industry for Still Charging and for handling Hot Oil, Fuller's Earth, Chlorine Treating Solutions, Mineral Seal Oils, Naphtha, Brine, Water, etc.

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## Gain in Demand for Heating Oils in 1933

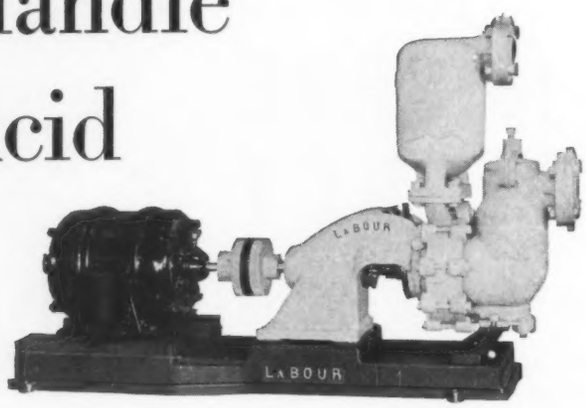
A STEADILY growing demand for range oil and domestic heating oils during 1933 is indicated by reports submitted to the United States Bureau of Mines by petroleum refiners. Deliveries of range oil increased 44.0 percent, or from 6,841,000 barrels in 1932 to 9,849,000 barrels in 1933. With average prices for domestic heating oils but slightly higher in 1933 than in 1932, with unusually cold weather prevailing in most parts of the country where oil burners are used extensively, and with about 75,000 new domestic burner installations requiring fuel, sales of domestic heating oils—grades No. 1 to No. 4, including furnace oils—were nearly 5,000,000 barrels above the 1932 total. The reported deliveries of these oils in 1933 were 34,140,000 barrels, or 16.7 percent above total deliveries of 29,264,000 barrels in 1932.

The use of range oil, an oil of about 40-43 gravity with many of the characteristics of kerosene, has been confined chiefly to New England; however, there is a growing demand for this grade of oil in New York State and in the rural communities of the northern tier of the Central States, where natural gas is not readily available.

In compiling data on the distribution of fuel oil for the Bureau of Mines, some refiners have experienced difficulty in breaking down their sales of light heating oils into "furnace oil" and "domestic heating oils." Because of this it is no longer possible for the Bureau of Mines to maintain separate classifications, hence "furnace oil" is now included under the general grouping of domestic heating oils, or grades No. 1 to No. 4.

The total deliveries of 34,140,000 barrels of domestic heating oils represent a gain of 16.7 percent above those of 1932 compared with a gain of 17.8 percent in 1932 over 1931, but a decline of 3.6 percent in 1931 from 1930. The substantial gain in sales of range oil and domestic fuel oils in 1933 appears to bear out the contention that the average prospective customer for an oil burner regards the price of the oil as secondary to the factor of convenience. In general, the increased cost of the fuel has been returned to the owners of oil burners in the form of increased mechanical efficiency; furthermore, the latest type of burners utilize heavier grades of oil than the burners of several years ago, thus effecting a saving in fuel costs.


# The *Economical* Way to Handle Acid

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**Economy of time, of labor, and of maintenance costs follows the installation of LaBour pumps for handling corrosive liquids in refineries. Available in self-priming or gravity feed types, they start to move liquid promptly and certainly whenever they are called upon. The self-priming type provides extraordinary safety due to the fact that much of the line can be at less than atmospheric pressure. The hazards of bottom outlets and gravity feed are completely excluded.**

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**Let the experience of the LaBour organization help you. This organization has long specialized in the problems involved in handling and conveying liquids in process plants. You'll be under no obligation or cost in asking for full information.**

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## Measurement of Oil in Bulk

AS a result of an extended study by one of its committees, the Institution of Petroleum Technologists, London, England, issued a report on "Measurement of Oil in Bulk." There has been a need for an authoritative publication on the subject of the various national fundamental units generally used in the petroleum industry and with the cooperation of the Standards Department of the Board of Trade, National Physical Laboratory, National Bureau of Standards (U.S.) and the International Bureau of Weights and Measures the report was prepared.

In addition to sections dealing with Fundamental Units, Relative Values and Tables of Inter-Relation of Units, there was included an interesting paper on "Historical Notes on the Principal Units of Weights and Measures."

Copies of this publication, in cloth cover, can be obtained from A.S.T.M. headquarters at 85 cents per copy, postage prepaid. As a service to A.S.T.M. members, there will be announced from time to time publications issued by the I.P.T. The Institution is reciprocating this service and has copies of A.S.T.M. publications of interest to its members, for sale at its offices, Aldine House, Bradford Street, London, W. C. 2.

## Handbook of Chemistry And Physics, 19th Edition

FOR 21 years the Handbook of Chemistry and Physics, published by Chemical Rubber Publishing Company, has been giving service to those in need of accurate tables, formulae and scientific data in a single convenient volume. The current or Nineteenth Edition of the handbook, represents a 21year accumulation of necessary data for the busy scientist and engineer that is both essential and acceptable in commercial, educational, routine and research laboratories. The current edition of 1934 pages includes such important data as, 274 pages of mathematical tables and formulae, 956 pages of chemical tables including physical constants of 4000 organic compounds and physical constants of 4000 inorganic and metal-organic compounds. There are 44 pages on properties of matter, 146 pages on heat, 114 pages on sound, electricity and magnetism, 70 pages on light, 283 pages of measure and units and many other useful tables and information of interest to all workers in the sciences. The book includes 18 new and important tables and most of the older important tables have been revised, enlarged and brought up-to-date.

The handbook simplifies the use of all textbook material and provides a short cut to conclusions, making easier the working out of a number of problems. The book is made easier to use since it has been divided into five sections, approximately equal in size. These sections are indicated by inserts of stiff colored paper on which is printed a summary of the contents of that particular section. This summary supplements the complete table of contents in the front of the book and the cross index in the back of the book.

Copies can be secured through the book department, Gulf Publishing Company, 3301 Buffalo Drive. Price $6.00.

## Patent Office Library

RECENT discussions pertaining to possible improvements in American patent practice which have appeared in Industrial and Engineering Chemistry have brought to attention a condition in the scientific library of the Patent Office which is of direct concern to the industry we serve.

The patent examiner must rely entirely on printed publications for anticipating inventions claimed to be new. Unfortunately, there is a large amount of literature, particularly in the chemical field, which is not available to these examiners. Owing to a lack of funds appropriated to the Patent Office and notwithstanding its considerable earning power, subscriptions have been discontinued to many important periodicals. The risk is even run of being unable later to complete sets of important journals which have been kept on file since their initiation. The acquisition of recently issued books, monographs, and indexes has been sharply curtailed, and in some cases the examiners themselves, in sheer desperation, have purchased reference books in the effort to conduct their work in as respectable a manner as possible.

The conditions are not to be blamed upon the officials of the Patent Office, who are doing as well as anyone could under the circumstances. The chemical industry, however, must impress upon Congress the importance of allotting sufficient funds for acquiring complete reference facilities, without which great damage may easily be done to the issuance of patents and costs thereby incurred out of any proportion to the sums involved in maintaining adequate literature facilities. (News Edition Industrial and Engineering Chemistry, Nov. 10, 1934.)


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*the famous* **EMPIRE BALANCED PISTON**

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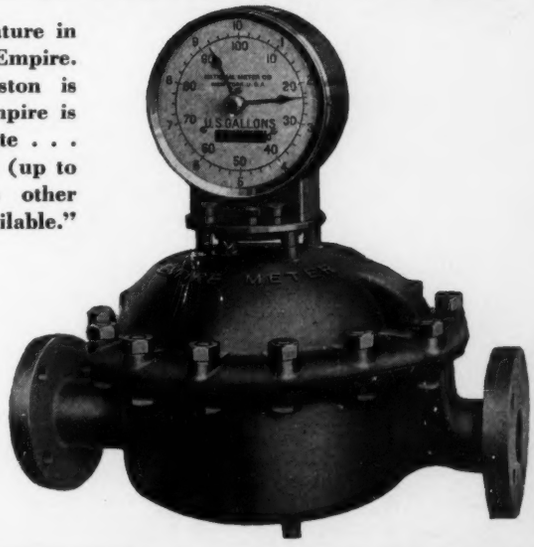



STANDARD AND HIGH PRESSURE TYPES FOR ALL LIQUID PETROLEUM PRODUCTS

**NATIONAL METER COMPANY**

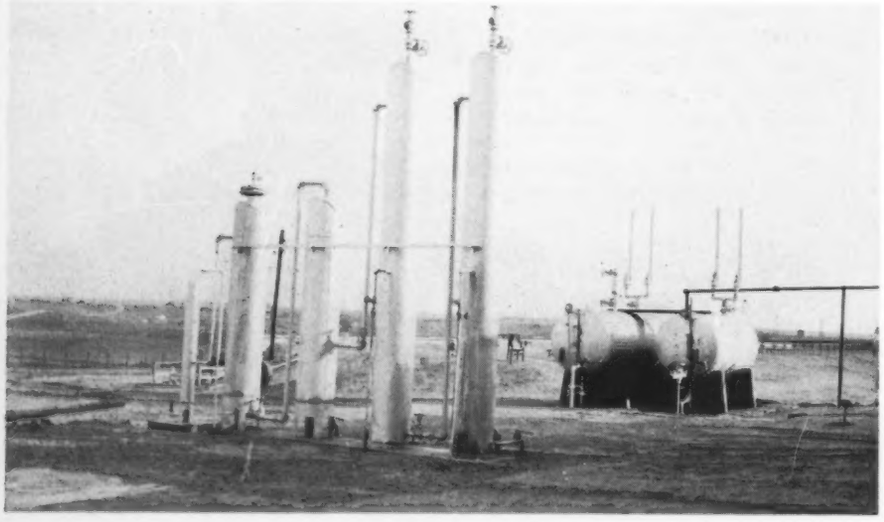
*Executive Offices and Factory:* 4213 First Avenue, Brooklyn, New York
*Southwestern Branch:* 1208 Dallas Bank and Trust Building, Dallas, Texas
BOSTON CHICAGO LOS ANGELES SAN FRANCISCO

## Treater and Drier For Liquefied Gases

TO become a satisfactory fuel for domestic consumption propane must not only be practically pure and free from heavier hydrocarbons, but must not contain moisture which will settle out in the containers or bottles after they are filled. The liquid propane must also be "sweet" and non-corrosive to avoid fouling of regulators, sticking of control valves and damage to burners.

In finishing this product Skelly Oil Company chemically treats it with caustic soda and sodium plumbite solution and separates all moisture in one continuous operation through a battery of five small columns operating in series. The first two columns in the series are used for contacting the propane with caustic and sodium plumbite. The first tower is operated by taking a split stream from the main gasoline caustic treating pump and circulating this chemical through the column. Propane passes from this base of the column to the top outlet, contacting the caustic in its upward flow and in this manner any hydrogen sulfide present is removed. Passing to the next column, a split stream of sodium plumbite which is also taken from one of the main treating plant pumps, is circulated counter-current to the flow of propane. It is sweetened in this column but a small quantity of the chemical remains in suspension. The third column is used as a settling tower or scrubber for the removal of suspended chemical.

The fourth column in the series is termed the "drier." This tower is constructed with two removable flanged openings, one at the top and the other as a manhole placed near the base. To prepare it for operation, both openings are unflanged and all material inside of the tower is removed. The lower opening is securely closed and the column is filled with unslaked lime through the opening at the top. The unslaked lime absorbs and removes water from the propane as it passes upward through the irregular chunks and pieces. The amount of lime necessary for operating the drier depends upon the volume of propane being treated and its condition when it enters the column after leaving the scrubber. When it is necessary to refill the drier with lime, both flanges are removed and the spent lime removed and fresh material is added. As the propane leaves the drier column, it enters a final scrubbing column installed to prevent any lime or other substance from passing to the storage tanks.



***Skelly Oil Company's propane treating and moisture removal plant at its Shafer gasoline plant***

## The Engine Indicator

THE Engine Indicator by H. J. De-Juhasz, assistant professor of engineering research Pennsylvania State College, published by the Instruments Publishing Company, 330 West 42nd St., New York, is a modernized treatment of modern indicators for the users of high efficiency steam and internal combustion engines. The purpose of this book is to present the history, theory and construction of the many forms of pressure indicator from its inception to the present day.

Information presented in this 240-page book is valuable not only for engineers in power plants, pumping stations, truck and bus fleet shops, engine factories, and automotive and aeronautical research laboratories, refineries and gasoline plants, but for all engineers who have to investigate forces and motions, and particularly for those who may have no interest in engines but who are concerned with variable pressures. The following chapter headings are indicative of the valuable contents of the book: Early history of the indicator; normal type indicators; general arrangement and component parts of normal type indicators; indicators for special purposes; high speed engine indicators; indicators for high pressures; maximum pressure indicators; mean pressure indicators; testing and calibrating the indicator; analytical theory of the indicator.

Over 300 separate illustrations add to the clearness of the text and increase the value of the book to the busy engineer. Price, $3.75.

## Revisions of Petroleum Standards Are Approved

IN accordance with recommendations from the Committee for Methods of Testing Petroleum Products and Lubricants and from the American Society for Testing Materials, which has assumed leadership in the work of the committee, the American Standards Association has approved revisions of the following standards, with designations as given:

Abridged Volume Correction Table for Petroleum Oils—Z11.1-1934 (A. S. T. M. D 206-34)

Cloud and Pour Points—Z11.5-1934 (A. S. T. M. D 97-34)

Sulfur in Petroleum Oils Heavier than Illuminating Oils—Z11.13-1934 (A. S. T. M. D 129-34)

Copies of these standards in their revised form are included in the Report of Committee D-2 on Petroleum Products and Lubricants of the American Society for Testing Materials. The report, a volume of 335 pages, summarizes all of the activities of Committee D-2 for the past year and also includes the complete text of the standards for testing petroleum and its products. Of the 53 methods of test published, 38 have been adopted by the A. S. T. M. as standard and 15 are published as tentative. Thirty-one methods of test and three methods of testing bituminous materials, all of which have been approved by the ASA, are included. A. S. T. M. standards or tentative standards for testing bituminous materials and electrical insulating oils are also included. The Standard Methods of Testing Electrical Insulating Oils—C59.2 (A. S. T. M. D 117-33) is among the group recently submitted by the A. S. T. M. for approval as American Standard as a result of the deliberations of the new Committee on Electrical Insulating Materials.

Tentative specifications for fuel oil

and Diesel-Fuel-Oil, the latter of which is being published for information in response to urgent requests, are included. Tentative specifications for five types of emulsified asphalts are among the new standards appearing in this volume for the first time.

Definitions of terms relating to materials for roads and pavements and tentative definitions of terms relating to petroleum are a part of the publication.

Copies of the report may be obtained from the A. S. T. M., 260 South Broad Street, Philadelphia, or may be purchased or borrowed from the ASA. The price is $1.75 a copy.

Copies of the individual standards recently approved are also available from the American Society for Testing Materials at 25 cents each.

WILLIAM LANGE, chief engineer of Wadhams Oil Company refinery at East Chicago, Indiana, (branch of Socony-Vacuum) embarked December 1 on the S.S. Europa for a trip to the continent. In addition to visiting various refineries of interest there he plans to spend some time with his family in Germany before his return late in January.

# ▼ PLANT ACTIVITIES ▼

**Purchase:** Lion Oil Refining Company, El Dorado, Arkansas, has purchased from J. D. Wrather, the Overton Refining Company, Overton and Kilgore Refining Company, Kilgore, each rated at 3,000 barrels capacity. The sale includes 71 wells in the East Texas field and 350 acres of leases.

**Refinery:** International Petroleum Company has been formed by J. R. Parten, president of Woodley Petroleum Company, Shreveport, associated with Sylvester Dayson, Baird, Texas, to erect a modern 2,500-barrel skimming and cracking plant at Reed's Switch, west of Kilgore, East Texas field.

**Resume:** Omar Refining Company, Garber, Oklahoma, has received approval for a $100,000 loan from R. F. C. and the company plans to resume operations at the refinery. Capacity 4,500 barrels, with a 2,500-barrel Winkler-Koch cracking unit.

**Tankage:** Gulf Refining Company, Port Arthur, Texas, has placed contract with Petroleum Iron Works, for 280 tons of steel for 11 new tanks.

**Tankage:** Atlantic Refining Company, Point Breeze, Philadelphia, Pa., has placed contract with McClintic-Marshall Corporation, for 200 tons of steel for new storage tanks.

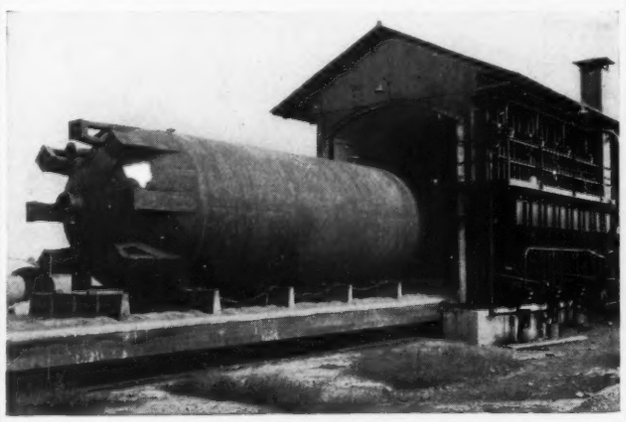
**Tanker Repairs:** The Texas Company has awarded contract for 600 tons of steel for repairs to tanker to Sun Shipbuilding & Dry Dock Company.

**Gas Lift:** Sloan & Zook Companies, 101 Main St., Bradford, Pa., reported planning installation of air and gas lift plants for oil recovery work various locations in Warren, Crawford and Venango Counties, Pa., H. K. Daugherty, engineer.

**Solvent Plant:** The Texas Company, Port Arthur, reported making definite plans for the early installation of a solvent treating or solvent extraction plant. Company owns two processes —furfural and acetone-benzol.

**Repairs:** Hercules Gasoline Company, Kilgore, Texas, is repairing damages sustained by its natural gasoline plant as the result of an explosion November 23.

**Refinery:** Phoenix Refining Com-

THIS VESSEL PASSED DUAL INSPECTION

The above vessel was unusual in that it was designed to meet the requirements of both the Canadian Interprovincial Code by special registration and the A.S.M.E. Code for Unfired Pressure Vessels, and, therefore, had to be inspected and stamped by qualified inspectors from both the Quebec Department of Labor and the Hartford Steam Boiler Inspection and Insurance Company.

The vessel is 9 ft. 6 in. I.D. x 23 ft. 10¾ in. long in the straight x 33 ft. 0 in. long overall x 1¼ in. hemispherical bottom head x 1⅛ in. shell x 1⅜ in. dished and flanged top head, and is provided with a special 16 segment internal bottom cone for supporting the charge. It was of fusion welded construction, annealed, X-rayed and designed for a working pressure of 160 p.s.i., subjected to a hydrostatic test pressure of 320 p.s.i., and hammer-tested at 240 p.s.i.

Send us your inquiries

J. P. DEVINE MFG. CO., Inc.

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MOUNT VERNON, ILL.

For More Efficient Spray Distribution

ALMOST any type of spray nozzle will increase the efficiency of a cooling system not already so equipped.

Marley patented spray nozzles provide the maximum of improvement because they are free from clogging, provide a finer, more uniform spray and operate efficiently under low pressures.

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PATENTED SPRAY NOZZLES

pany, Abilene, Texas, is nearing completion of an 800-barrel skimming plant near the Condor-Sayles oil field, Jones County. Materials derived chiefly from dismantling of the company's original plant near Dallas.

**Solvent Plant:** The Pennzoil Company, Oil City, Pa., announces that since June 1 it has been treating 1,000 barrels daily of Pennsylvania grade crude lubricating stock through its Chlorex solvent refining plant completed this summer.

**Italian Refineries:** It is currently reported that the activity in construction of new refineries and enlargement of existing plants next year in Italy will involve expenditure of $15,000,000 to $20,000,000. See Refiner, September, 1934. Page 327 for list of companies involved.

**Refinery:** The Cork Harbour Oil Wharves, Ltd. (subsidiary of Oil Wharves, Ltd.) at Haulbowline Island, Ireland, is progressing rapidly in construction of its 600-barrel refinery, Distillation unit contract to Foster Wheeler Corporation.

**Gasoline Plant:** Royalite Oil Company, subsidiary of Imperial Oil, Ltd., is planning construction of a second natural gasoline plant in the Turner Valley field, Alberta, Canada. Maturity, spring of 1935.

**Refinery:** Anglo-Persian Oil Company is erecting a refinery 2½ miles east of the town of Kermanshah for supplying north and northwest Persia. The plant wlil process oil from the Naft-i-Shah field. The refinery consists of pipe still, fractionating column, condensers, receiving tanks, acid treating plant, and crude storage. Auxiliaries consist of boiler plant, storehouse, offices, and Diesel engine-driven electricity generating plant.

**Receivership:** Spartan Refining Company's 12,000-barrel skimming and cracking plant at Jewella, suburb of Shreveport, Louisiana, is temporarily shut down, with shipments continued from stocks on hand. The company with its affiliated company, Atlas Pipe Line Company, went into receivership late last month, but both companies will be continued as going concerns.

**Enlarge:** Rado Refining Company, W. K. Campbell, McAllen, Texas, plans to enlarge its refinery at estimated cost of $40,000.

**Cracking Plant:** Comet Oil Refineries, Ltd., at Point-aux-Trembles, on the St. Lawrence river near Montreal, Canada is erecting a Dubbs cracking unit of about 2,000 barrels capacity and a pipe still distillation unit with capacity of about 3,000 barrels. The company is affiliated with Emerald Petroleum Company, Dallas, Texas, which will furnish crude from Texas-Louisiana points by tanker. W. J. McCormack is president of Emerald Petroleum Company and vice president of Comet, and O. S. Knisely, vice president and general manager of Emerald is president of Comet. Contract to Geo. A. Fuller Construction Company.

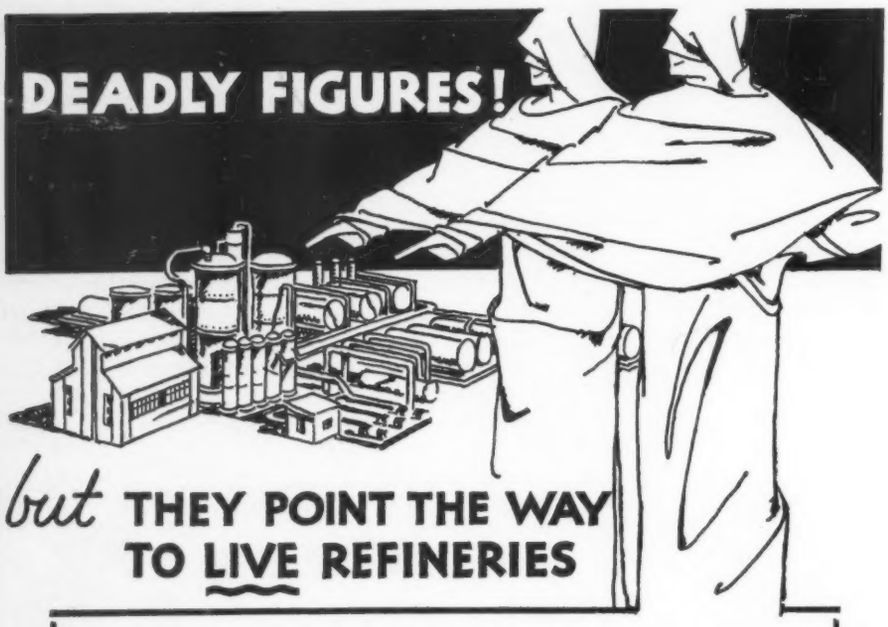
**Terminal:** Sinclair Refining Company, West Springfield, Mass., is building a two-story brick terminal plant, including warehouse, pump house and steel tanks. Estimated cost about $35,000.

**Solvent Plant:** Standard Oil Company of Louisiana is about ready to begin operation of its new 2,000-barrel phenol solvent plant at Baton Rouge.

**Solvent Plant:** Humble Oil & Refining Company, Houston, completing plans for erection of a phenol solvent treating plant of capacity reported at 2,000 barrels.

**Solvent Plant:** Gulf Refining Company, Port Arthur, Texas, reported completing plans for early installation of a new solvent refining plant.

**Solvent Plant:** Sinclair Refining Company, Houston, is reported planning installation at its Sinco refinery, a modern solvent refining process for production of lubricating oils.


but THEY POINT THE WAY TO LIVE REFINERIES

KINNEY PUMPS—Grand Summary of Repair Part Costs of 14 Companies.

| | |
|---|---|
| Total Number Pumps | 1685 |
| Total Cost, New | $1,435,981.56 |
| Total Repairs Furnished | 214,857.65 |
| In Service 1-20 years, average age | 9.2 years |
| Cost of Repairs, per pump, per year | $13.88 |

or, 1.63% of first cost for repairs, per year!

To the man on the outside these are deadly figures.—To you on the inside of refineries who have seen KINNEY PUMPS actually making these records—pumping all kinds of materials under all sorts of conditions—the figures are full of life and meaning.

For you know that the refinery equipped with Kinneys is enjoying the low cost pumping and the freedom from shutdowns that mean everything to the men charged with production.

You will want the brand new Kinney Pump Bulletin, address—

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3539 Washington St.
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517 Finance Bldg. KANSAS CITY, MO.
1333 Santa Fe Ave. LOS ANGELES

# New Equipment for the Modern Plant

## Welding Bench
**OSTER-WILLIAMS**

Oster-Williams, 2057 East 61 St. Place, Cleveland, has announced the addition of a new pipe welding assembly bench.

This fixture is capable of handling all sizes of pipe up to 12 inches in diameter and will line up accurately and hold in position for tacking, fittings, flanges and branches at any angle. For handling longer lengths an extension bench can be supplied. The extension can be moved to any angle to the main bench. An adjustable elevator, which can be used at any position on the main bench or on the extension, controls the vertical alignment of the work. Accurate angle alignment is obtained by setting elevator to desired angle. Elevator supports are graduated to make setting easy.

The general construction of the bench, makes for solidity without excessive weight. The main bench and extension consist of an eyebeam mounted on tubular legs, with sufficient spread to eliminate tipping. Elevating and VEE supports are all steel. The main bench weighs 700 pounds and the extension 300 pounds. The bench can be disassembled for portability and reassembled quickly and easily. The dimensions of the main bench eyebeam are eight feet long, by one foot wide and the extension six feet long by one foot wide. Their height is two feet.

## Arc Welding Equipment
**GENERAL ELECTRIC COMPANY**

General Electric Company, Schenectady, New York, announces that in addition to its line of direct current arc-welding equipment it now has available a complete line of alternating arc-welding equipment including transformer units, electrodes, and automatic welding heads and control.

The new a-c equipment is intended for heavy-current welding—primarily automatic welding because of the heavy currents involved, but otherwise equally well suited to hand applications.

A-C arc welding is not new, but the remarkable development of arc-welding electrodes during the last few years has only recently made it possible to benefit from the major advantage of the a-c process—that advantage being the absence of magnetic blow in the arc, and therefore superior quality in the resulting weld. It follows, of course, that this advantage becomes particularly apparent with the heavier welding currents (above 250 amperes) because of the greater magnetic effect at these currents. Slightly greater welding speeds are possible when using a-c, and in making fillet welds and in working into corners and other parts of intricate structures, the a-c arc permits full penetration to be obtained.

The new transformer units are available in three sizes having one-hour ratings of 500, 750, and 1000 amperes. Primaries are wound for 220, 440 or 550 volts; 60, 50, or 25 cycles; single phase. Extra attachments are available for reducing the secondary open-circuit voltage to approximately 50 percent of its normal value (normal being 80, 90, or 100 volts), and for obtaining currents down to 10 percent of the one-hour rating.

The transformers themselves are of the high-reactance type, air-cooled and enclosed in a sturdy cylindrical shell. A suitable arrangement is provided to vary reactance so that the full welding range of the equipment can be obtained on any one of three secondary open-circuit voltage settings—the latter being selected by means of taps on the primary winding.

The electrode recommended for the a-c process is the General Electric Type W-23, a heavily coated electrode suited to a-c welding.

The new a-c equipments are intended primarily for shop use in semi-permanent locations, a lifting eye being provided on top of the transformer unit by means of which the set can be readily moved by a crane.

## Pipe Tools
**THE BORDEN COMPANY**

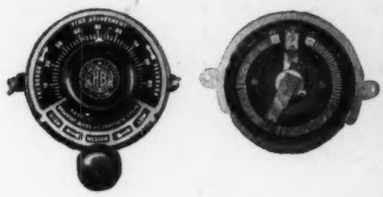
The Borden Company, Warren, Ohio, has introduced two new pipe tools, the No. 6-R Beaverette Ratchet, and the No. 38-R Beaver Ratchet.

The No. 6-R ratchet threads ¼-, ⅜-, ½- and ¾-inch pipe without changing dies or bushing. It was designed to facilitate work in ditches, corners, or close to walls. Dies are also available for ⅛-inch pipe.

*New Borden Pipe Tools*

The No. 38-R ratchet model cuts 2½- and three-inch standard pipe thread (eight thread), or two-, 2½- and three-inch oil well casing thread (11½ thread). Either combination is available. This type is the three-inch model of the company's well known two-inch model.

## Volt Amp Adjuster
**THE HOBART BROTHERS COMPANY**



The Hobart Brothers Company, Troy, N. Y., has perfected a new volt amp adjuster for the purpose of securing finer adjustment in remote control of Hobart welding machines and it is now standard equipment on such machines. The improvements are said to give the operator more than 140 combinations of voltage and welding current, right at the finger tips, no matter how far away he is working from the machine, for each of the machine ranges, therefore approximately 430 different combinations are available, one third of which may be selected without going near the machine when using the remote control feature.

## Automatic Tank Gauge
**IMPERIAL INSTRUMENTS, INC.**

Imperial Instruments, Inc., Akron, Ohio, announced development of a new type of liquid gauge which has been undergoing field tests for the past two years and a number of installations have been made for the largest oil distributors in Ohio. The accompanying diagram shows the hydrostatic principle of operation of the gauge. The liquid in the tank is connected by means of copper tubing to a bellows type, metal diaphragm which is linked mechanically to the indicator of the gauge. As the tank is filled the diaphragm expands, the linkage moves the indicator and the reading on the dial shows the exact quantity in terms of gallons, pounds, barrels, inches, or any desired unit.

The measurement is based on pressure and therefore on weight. This means that the gauge may be calibrated to show the correct volume at any specified temperature. In the case of gasoline this is 60°F.,

and eliminated the necessity of making temperature corrections.

Where automatic valves are used, it is possible to compensate for vapor pressure by connecting the diaphragm housing with the top of the tank by means of copper tubing.

These gauges are built to measure liquids in tanks ranging in capacity from 300 gallons to 3,200,000 gallons. Crude oil, kerosene, motor oil, fuel oil, etc., may be measured.

In the measurement of gasoline, the advantages claimed for this gauge are that it eliminates temperature readings and corrections and gallonage computations; that it eliminates the hazard of opening up tanks and reduces evaporation losses; and that its use decreases the time required for keeping inventory records as well as increasing the accuracy of these records.

## Oxweld Cutting Machine

**THE LINDE AIR PRODUCTS CO.**

The Linde Air Products Company, 30 East 42nd Street, New York, N. Y., has just announced a new addition to its line of oxy-acetylene cutting machines, The Oxweld Monitor or CM-8 Cutting Machine. It is of extremely rugged construction, stream-lined to facilitate both operation and maintenance. It is easily portable, and is adjustable through the entire range of oxy-acetylene cutting. All the working elements are enclosed in a double cover.

The Oxweld Monitor does automatic straight line cutting of practically unlimited length, straight bevel cutting, two bevels at a time if desired, plate edge preparation, circle or ring cutting of diameters up to 100 inches and the cutting of curved or irregular shapes.

One blowpipe, the Oxweld C-7, is supplied as standard equipment, thus permitting cuts up to 12 inches. The Oxweld C-22 blowpipe may be substituted for heavier cutting and certain flame machining operations. Provision is made for the use of two blowpipes simultaneously. These can be mounted either on the same or opposite sides of the machine, and adjusted independently. The slide for the blowpipe holders is constructed so that it may be swung instantly into any horizontal position over a working arc of 250 degrees. Protractor scales gauge the tilting of the blowpipes in their direction parallel to the side of the machine through 90 degrees, and up to 90 degrees at right angles from the side.

Special care has been given to speed control, and the sensitive indicators eliminate all guess work. Merely by setting the indicator and shifting the gear lever any speed may be instantly obtained within the range of two to 48 inches per minute. The location of the speed regulator near the guiding handle of the machine makes possible to alter the speed at an instant during cutting without stopping the work.

The unit comes complete, ready to plug into the power line. It is supplied with blowpipe and assorted nozzles, two six-foot lengths of track, and a radius attachment.


*N. G. E. Column Type*
LIQUID LEVEL CONTROLLERS

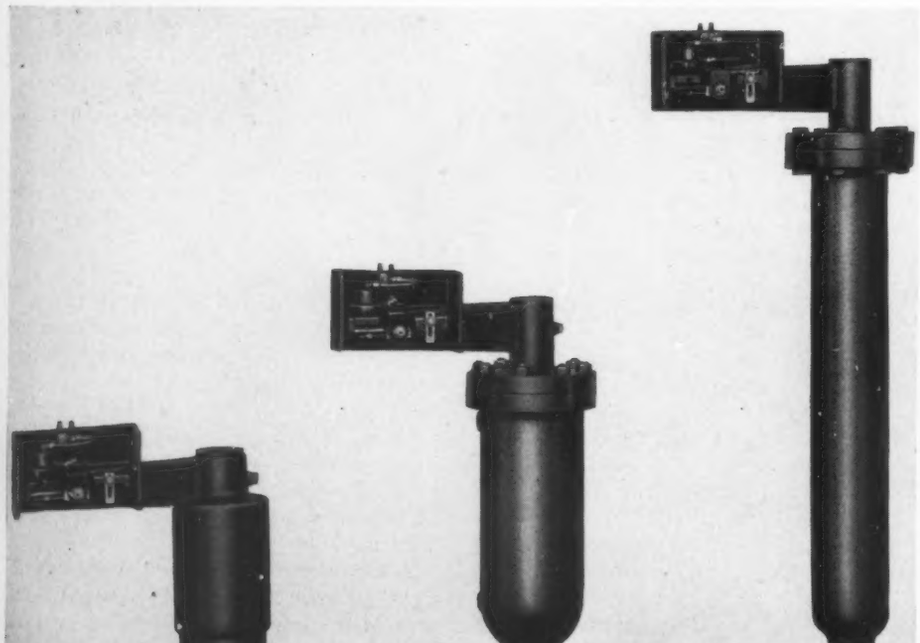
*N. G. E. Liquid Level Controllers*
*Column type pilot operated*
*Remote control ball float type*
*Direct acting ball float type*
*Either of above for external or internal mounting.*
*Special enclosed stuffing box type for low temperatures and solvent plant use.*

In the N. G. E. column type liquid level control the pilot mechanism is an integral *built in* part of the unit. It is designed for compact, simple operation and affords wide flexibility in throttling range. Because it may be adjusted so that level may vary up to the limit of float length, it is possible to hold a uniform flow of liquid into or out of the vessel, regardless of sudden but temporary changes in liquid level, or so-called "surging." The *built in* precision pilot mechanism weights the displacement of the float. These controllers are available in 7", 14" and 30" float lengths and in cast iron construction for low pressure—steel construction for high pressure or high temperature.

*Write for information*

**NATURAL GAS EQUIPMENT INC.**

**Los Angeles - - - - - - - - - Petroleum Securities Bldg.**
**San Francisco - - - - - - - - - 1123 Harrison Street**




## Ball Bearing Regulator

**MASON-NEILAN REGULATOR CO.**

Mason-Neilan Regulator Company, Boston, Mass., announces a new pressure reducing regulator. This regulator is known as the No. 505 Series and is equipped with non-corrosive stainless steel ball bearings which roll up and down with the valve stem travel and reduce friction to a minimum. Ball bearings also turn freely under the spring adjusting screw and permit pressure settings to be easily accomplished.

Flexible, multiple springs permit the use of larger diaphragms and are said to increase the sensitivity and accuracy of the regulation. A self-aligning spring button prevents spring tilt and side sway from interfering with smooth operation. These regulators are equipped with the

Centroguide valve, an advanced type of valve in which the valve plug is centrally guided at the top and bottom of the valve body. It is claimed that this practically eliminates wire drawing and cutting of the valve plug and valve seat rings. Grease sealed stuffing boxes can be furnished for those services where it is desirable.

## Gas Mask Facepiece

**E. D. BULLARD COMPANY**

By enlarging the exhalation valve on its new facepiece to approximately double the size commonly used, E. D. Bullard Company, San Francisco, has decreased fogging of the eyepiece, lowered exhalation resistance and made possible conversation through the facepiece.

*Bullard Gas Mask*

Under normal working conditions, this lowered exhalation resistance adds to the comfort of the wearer, and decreased fogging of eyepieces makes the facepiece more efficient in use. Workmen in the same room may talk to each other, or bosses may direct the activities of the men in safety by talking their instructions. In smoke filled rooms where signalling is difficult, orders may be given orally.

## Vacuum Equipment

**GOSLIN BIRMINGHAM MANUFACTURING COMPANY**

Goslin - Birmingham Manufacturing Company, Birmingham, Alabama, has introduced a new line of oil-sealed high vacuum pumps, together with new single- and two-stage vacuum ejectors. The pump is of the truly rotary type, without eccentric-shaped parts, cams or reciprocating elements. The internal parts are centered and revolve only. This construction is said to permit high speed without vibration, although even the smallest size operates at only 400 r.p.m. The pump is mounted on a base which serves as the reservoir for the lubricating and sealing oil, and which contains a cooling coil for maintaining the proper oil temperature and condensing any water vapor drawn into the pump. This line includes five sizes with displacements ranging from 12 to 200 cubic feet of free air per minute, and capable of pumping down to a vacuum of a few microns.

The ejectors are of the steam-jet type, with high tensile strength, cast-iron bodies and alloy nozzles. They range in size from 1½ to six-inch suction, giving capacities from 75 to 800 cubic feet of free air per minute, and producing vacuum of 26 inches in the single-stage model.

## Welding Outfits

**LINDE AIR PRODUCTS COMPANY**

Linde Air Products Company, New York, recently announced two additions to its Prest-O-Lite line of equipment for soldering, brazing and heating. These new outfits, the Prest-O-Lite 4-in-1 Outfit, and the Prest-O-Lite Plumber's Outfits, maintain the high standard already set by the Prest-O-Lite 5-in-1 Outfit, according to the manufacturer.

The new 4-in-1 outfit was assembled and is presented to the trade for the benefit of those who found the 5-in-1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***Write today for prices and full information.***

**Solvay Sales Corporation**

***Alkalies and Chemical Products Manufactured by The Solvay Process Company***

**61 Broadway** **New York**

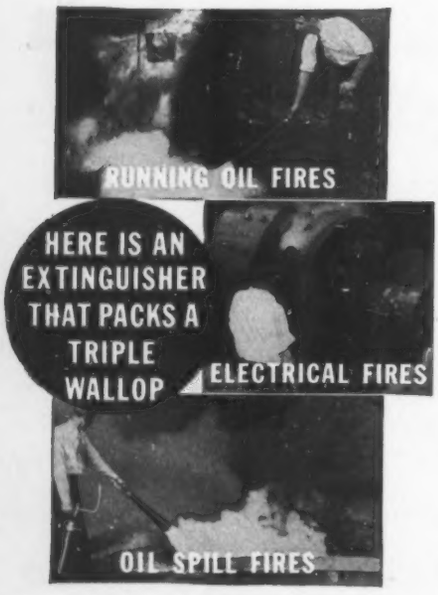
## Who will Bet on a One-Armed Fighter?

SOME fire extinguishers, like a one-armed fighter, have only one punch. They will put out only one kind of fire.

LUX extinguishers, however, pack a triple wallop against the fires that most frequently occur at refineries and bulk plants. They put out fires in oil and gasoline spills on the ground, fires in oil pouring from a cracked fitting or overflowing tank truck and fires in electrical apparatus. No other type of extinguisher is effective against all three.

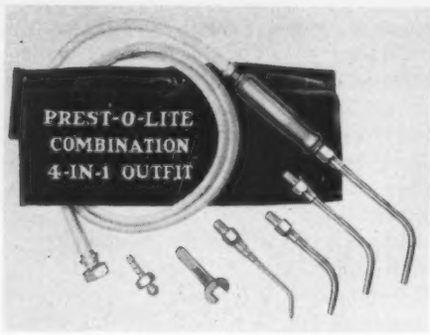
That is one reason why leading oil companies are adopting LUX. Other reasons are that LUX extinguishers require refilling only when used and will not freeze in the coldest winter weather.

You can't tell beforehand what your next fire will be. But with LUX, you will have protection against three kinds of fire instead of one. May we send you descriptive literature? Walter Kidde & Company, Inc., Dept. B-8, Bloomfield, New Jersey.




**LUX EXTINGUISHERS**

**For Refineries—Bulk Plants—Trucks**




outfit more comprehensive than necessary for the particular line of work in which they were engaged. It differs from the 5-in-1 outfit in that four stems instead of five (the soldering iron is omitted), and a durable, water-proof fabric carrying case, instead of the heavier metal case, are offered at a somewhat lower price consistent with the difference in equipment.

The four stems cover: fine soldering such as that used by jewelers, toy manufacturers, telephone repairmen, and for exact heating operations on delicate instruments; light soldering, brazing and heating, as for making soldered wire splices, and for auto, truck and tractor radiator work; medium soldering, brazing and heating, ideal equipment for sealing batteries, burning cable lugs and for all average open flame work; and heavy soldering, where the torch must furnish a large volume of heat sufficient for bending rod, straightening dented fenders and other automotive repair work.

The Prest-O-Lite 4-in-1 outfit is convenient to use in any position, in a corner or places that would be hard to reach with old-fashioned equipment. The small but intense flame may be focused exactly where it is needed. The handle—common to all the stems—is made of non-heat-conducting material which eliminates cracking, warping or loosening and is finished in stain and lacquer.

## Tape-Rule

### THE LUFKIN RULE COMPANY

The Lufkin Rule Company, Saginaw, Michigan, has just placed on the market its No. X686 extension tape-rule, a flexible type rule suitable for taking inside measurements of openings and for all standard measuring work. The rule was designed to take inside measurements even when both limits of the space are at bottom of a channel or groove.

The new rule has a sliding hook so the blade can be inserted in a narrower slot than the hook would enter. This is useful in measuring also, since it automatically adjusts itself so that when hooked over the article being measured zero falls at inside of hook. When blade is butted against any object, zero point is extreme end. In common measuring, the larger figures along the lower edge of the blade are read, while in inside measuring the smaller figures along the upper edge of the blade are read.

## Electric Motor

### U. S. ELECTRICAL MANUFACTURING COMPANY

U. S. Electrical Manufacturing Company, Los Angeles, has announced a new development in variable speed motors. Company engineers have incorporated as an inherent part of the U. S. varidrive motor an application of the Syncrogear. The varidrive motor now is available with gears for increasing or diminishing the speeds, thus enabling the operator to obtain an infinite number of speed selections. The syncrogear is mounted within a self-contained housing, which is part of the motor case. The take-off shaft is supported by a bearing housing machined to fit the companion-machined surface of the varidrive case. These single reductions, with their attendant high torques, may be safely attained without fear of excessive strains, due to the heavy ribbed construction of the varidrive case, it is claimed.

The U. S. varidrive motor embodies a unique principle of speed changes, so that the operator has at his command a motor with a thousand speeds, according to the manufacturer. By a turn of a wheel, micro-control of the rotations of the take-off shaft is obtained. This new unit consists of a simple squirrel cage U. S. asbestos-protected motor, built integral with a variable speed transmission and gear, thus embodying several machines in one. The speed is changed by varying the effective driving diameter of the varidiscs. The latter discs are mounted opposite each other. These discs expand and contract for higher or lower speeds, transmitting power through a varibelt to the take-off shaft. To change from one speed to another the operator turns a hand wheel. This actuates a traveling hub and lever arms which in turn increase or diminish the distance between the two sides of the driven discs. The lever arm syncronizes the action. A calibrated helical spring keeps the pulley connections in proper contact with the varibelt.

## Coupling

### WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania, has developed a new non-lubricated coupling said to provide a flexible shaft coupling which will compensate for slight misalignment without the requirement of periodic lubrication. It is known as Type WH and consists of two identical, cast-

steel, flanged halves joined together with from five to 22 flexible elements, depending on size. These torque transmitting elements consist of rectangular steel plates enclosed in cushioning elements made from high grade hydraulic packing. The torque elements are held in slots by means of retaining rings which snap into grooves and the whole assembly is covered with two sheet-steel cover plates. These present a smooth exterior and assure the safety of attendants.

## Bronze Gate Valves

**KENNEDY VALVE MANUFACTURING COMPANY**

Kennedy Valve Manufacturing Company, Elmira, New York, announces a new line of rising stem heavy standard bronze gate valves for 150 pounds working steam pressure and 250 pounds working water, oil or gas pressure.

This valve, known as Fig. 45, is a companion type to the new Fig. 23 with stationary stem which was introduced earlier in the year. The operating mechanism employs solid wedge discs which are simple, heavily proportioned and accurately machined, and with no small quick-wearing parts which might cause trouble in service. This mechanism has ben used for many years in other Kennedy valve types and has proven to operate with ease and certainty in any position.

A flexible connection is provided between the disc and the stem so that the stem will not bind or spring when the valve is closed. The stem is made of a bronze composition with high tensile and torsional strength, and has a large number of contact threads in the bonnet.

The bonnet hexagon has been made extra large and close to the body so that when a wrench is applied for installing or disconnecting, there will be no danger of distorting the bonnet. Additional features of this new design are the deep stuffing box with gland and square section molded packing rings, the large nonheating malleable-iron hand wheel which is secured to the stem by a nut, and the heavy, wide pipe-end hexagons with generous number of threads.

## Lubricators

**HILLS McCANNA COMPANY**

Hills McCanna Company, 2349 Nelson St., Chicago, announces improved force feed enclosed type lubricators, Model ET, types SF and BF, developed to meet the needs of industry for totally enclosed units. Type SF has a positive drip sight feed on the discharge side of the pump. Type BF is built without the built-in sight feed. The pump valves are single plunger type. All working parts are under the cover and in a bath of oil. The manufacturers state that they are accurate and dependable in regulation from one to 10 drops at each stroke against pressures up for the back-pressure valve, and two to 2000 pounds. The pump valves are interchangeable and can be individually removed. An auxiliary crank is provided for priming and flushing the oil lines and the oil gauge is recessed to prevent breakage. All parts are standardized and interchangeable.

## Acetylene Generator

**THE LINDE AIR PRODUCTS CO.**

The Linde Air Products Company, 30 East 42nd Street, New York, announces a new automatic stationary generator, known as the Oxweld Type MP-5, and which is rated to deliver 1000 cubic feet of acetylene per hour.

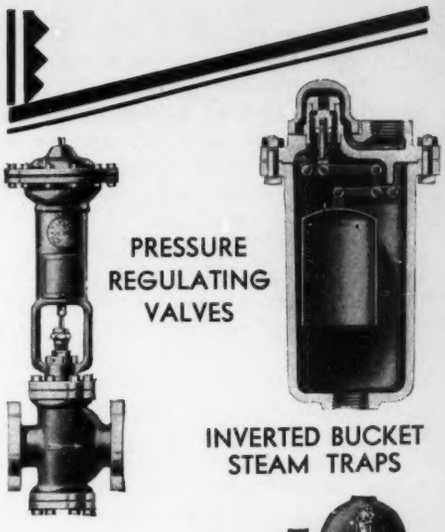
The feed is of the gravity type of advanced design. The feed control unit is self-contained and is bolted to the inside of the carbide hopper. The feed valve unit is actuated by a diaphragm. Pressure on the diaphragm is exerted by a housed and loaded spring unit. The spring is encased in a small housing and set at the factory to deliver about 13 pounds per square inch pressure. This can be changed within a range of about two pounds per square inch by an external adjustment. The set pressure feature does away with the necessity of setting the pressure when the machine is started. The pressure variation within the generator is not more than three quarters of a pound, and this veriation is nullified in the service line by the built-in Oxweld Type R-57 Regulator.

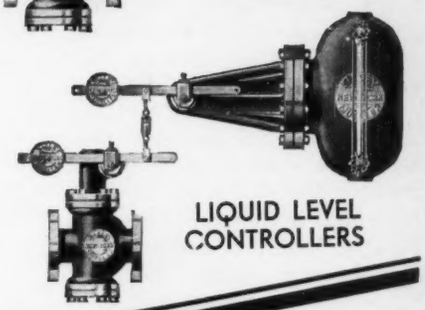
The carbide - charging door, the waterfilling opening, the residue valve, and the handhole have been built on generous proportions so that time can be saved in emptying, recharging, and inspecting. The carbide hopper affords the greatest operating efficiency combined with easy cleaning; and the regulator filter unit, with its large capacity pads, is within easy reach inside the handhole.

Instead of having an external hose connection manifold, it has the service valve which is necessary on a stationary machine on the service pipe that leads directly from the back-pressure valve.

A funnel and a three-inch lubricated water filled valve and vent cock take the place of a water-filling cap and overflow plug. The water-filling valve has an interference rod that operates the vent cock on a pipe leading to the outdoor vent line. This system makes it impossible to add water unless the cock is open to allow for the displacement of gas.

The relief valve arrangement on the Type MP-5 generator is particularly interesting. A separate relief valve with a separate outdoor vent line is provided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- Steam Traps
- Liquid Level Controllers

other relief valves with a common outdoor vent line are provided for the generator chamber. Two relief valves are used because of the high capacity of the generator, and also because it is easier to get good seating and prevent leakage when two valves are used instead of one large one.

The Oxweld Type MP-5 Acetylene Generator is provided with a hopper that has eyelets around the top so that it can be removed with a block and tackle. Since a charging platform is usually built alongside a stationary generator, none has been provided on the new generator.

To insure a gas tight seal and to lessen slaking when the generator is out of service for long periods, a soft rubber seat is provided on the hopper outlet.

The hydraulic back-pressure valve and the reservoir are combined in one shell. The reservoir protects against accidental loss of water from the back-pressure valve and prevents water from backing into the regulator. An intermediate valve on one side of the hydraulic back-pressure valve and the service valve on the other make it possible to check the water level without escaping gas or loss of water.

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# Items About Manufacturers

**Blaw-Knox Company,** Pittsburgh, announces appointment of Chester H. Lehman, formerly sales manager and secretary, to be vice president in charge of sales. Mr. Lehman dates his active affiliation with the company since 1909, or during the major part of the company's existence. In his new position he retains his directorship and also is secretary and director of some of the Blaw - Knox subsidiaries; Pittsburgh Rolls Corporation, Lewis Foundry & Machine Company, Union Steel Casting Company, National Alloy Steel Company, Blaw-Knox Construction Company, all of Pittsburgh; Hoboken Land Company, A. W. French Company and Blaw-Knox International Corporation.

**Mundet Cork Company,** 450 Seventh Avenue, New York, announces recent changes of addresses in their respective offices as follows: The address of the Cincinnati, Ohio, branch is now 427 West 4th Street; Detroit, Michigan, office is now located at 335 West Jefferson Street; the Memphis, Tennessee, offices, Medical Arts Building, and the Philadelphia office is now located at 2228 Arch Street.

**Sivyer Steel Casting Company,** Milwaukee, announces appointment of M. N. Dennenbaum Company, 1001 Shell Building, Houston, as its representative for the Gulf Coast district on refinery equipment. The company specializes in "Safety" return bends, alloy tube supports, heat resisting and stainless steel castings and other refinery fittings.

**The Duriron Company,** Dayton, Ohio, has announced appointment of M. L. Bettcher, formerly general superintendent, as general manager, succeeding Dudley H. Miller, who became executive vice president. The company also announces the following changes in branch office management: N. E. Philpot, who has been manager of the Chicago office for several years, is assuming charge of the New York office, succeeding W. E. Pratt, resigned. Col. M. W. Smith, former manager at Buffalo, is taking over the Chicago office. W. A. Watkins has been transferred from the general sales department at Dayton to Buffalo as manager.

**The Timken Roller Bearing Company** announces appointment of Whitley B. Moore as general manager of the industrial division. He has been sales manager of the industrial division since 1930. John L. Young, until recently district general manager, Pittsburgh office, for The Timken Roller Bearing Company has been advanced to the position of assistant general manager of the industrial division and is moving to Canton, Ohio, to take over his new duties. Harry D. Robb has been advanced to the position of district manager in charge of the Pittsburgh office. Harry H. Wood of the Canton headquarters offices has been transferred to Pittsburgh and appointed manager of the rolling mill division.

**Johns-Manville** has announced that its recently formed subsidiary, Johns-Manville Credit Corporation, through cooperation of the Federal government, is now able to finance industrial and commercial repair and modernization work at the lowest carrying charges ever offered in a deferred payment plan of the kind. The cost of financing is $5 per $100 per annum, the same as specified in the National Housing Act. The new corporation is capitalized at $1,000,000 to make credit for repairs and improvements easily obtainable. Payments are made in monthly installments over a period of from one to three years. Under this government approved plan many establishments will be enabled to make improvements and repairs without additional strain on their budgets.

**The International Nickel Company** announces that the district office of the development and research department in Detroit has moved into larger quarters in the General Motors Building. E. J. Hergenroether is district representative.

**Republic Steel Corporation** announces appointment of Robert J. Working as district sales manager in Cincinnaati. Formerly in the sales department of United Alloy Steel Corporation at Canton, Ohio, Mr. Working was placed in charge of the Cincinnati district office of Central Alloy Steel Corporation in 1927. Following the Republic merger in 1930 he was made assistant district sales manager of the Cincinnati office.

**Oster-Williams,** Cleveland, Ohio, manufacturers of pipe and bolt threading equipment, recently opened an office and display room at 292 Lafayette Street, New York City. The establishment is in charge of the firm's district manager, H. B. Van Osten. All machines on the display floor will be available for actual threading demonstrations.

# CATALOGS . . . BULLETINS

## *Helpful Publications Which Manufacturers Will Be Glad to Send Free for the Asking*

**Packing**
Johns-Manville Company, 22 East 40th Street, New York, has issued a 40-page book describing a wide range of packings covering more than 60 types, with complete recommendation tables.

**Pumps**
The Duriron Company, Dayton, Ohio, in Bulletin 172 describes a new series of centrifugal pumps for handling acids and alkalies.

**Tubing**
Summerill Tubing Company, Bridgeport, Pa., is distributing an interesting bulletin on some of the company's specialties in tubing, the line ranging from hypodermic needle tubing to tubing for oil and Diesel engines, heat exchangers and larger tubes. A discussion of the manufacture of steel tubing is presented.

**Packing**
The Garlock Packing Company, Palmyra, N. Y., is distributing a new bulletin on the company's new Klozure, oil seal. The booklet is well illustrated and includes all pertinent engineering information.

**Boilers**
The Babcock & Wilcox Company, 85 Liberty Street, New York, is distributing Catalog G-17, giving detailed information on its integral furnace boilers.

**Alkalies**
Southern Alkali Corporation, Corpus Christi, Texas, is distributing an attractive 16-page catalog presenting information about the new plant and various grades of soda ash, caustic soda, and the modified sodas being produced at the new Texas plant.

**Filters**
Filtration Equipment Corporation, 350 Madison Avenue, New York, has issued Bulletin L describing five types of filter equipment for a variety of industrial uses, including rotary vacuum filters, rotary vacuum dewaterers, open tank leaf filters, bar screens for removal of floating and coarse materials, and the automatic upflow magnetic sand filter.

**Vacuum Pumps**
Roots-Connersville Blower Corporation, Connersville, Indiana, has issued Bulletin 50-B11 devoted to new high duty vacuum pumps, including sectional views and illustrations of several installations.

**Respirators**
Pulmosan Safety Equipment Corporation, 176 Johnson Street, Brooklyn, N. Y., has issued a bulletin describing the M series of improved dust respirators.

**Iron**
Republic Steel Corporation, Massillon, Ohio, is distributing a new booklet called "Thumbs Down on Rust" giving reason for the rust resistance of Toncan Iron and illustrates a number of typical installations of Toncan sheet iron.

**Welder**
Hobart Brothers Company, Troy, N. Y., is distributing a new bulletin on a new 40-volt simplified arc welding especially designed for refinery, gasoline plant and pipe line work.

**Gaskets**
Flexitallic Gasket Company, 8 and Bailey Street, Camden, N. J., is distributing a new bulletin dealing with Flexitallic gaskets for pipe flanges, all boiler openings, waterwalls, economizers, superheaters, and pressure vessels. The booklet is well illustrated and includes full information on separate items of the wide line of gaskets.

**Gas Engine**
Worthington Pump and Machinery Corporation, Harrison, N. J., is distributing a new bulletin describing its vertical four-cycle gas engines, including drawings, and general specifications. Company is also distributing a bulletin on Worthington automatic power pump receiving sets, of vertical triplex single-acting type and a bulletin on its line of two-stage volute centrifugal pumps.

**Tools**
The Borden Company, Warren, Ohio, is distributing a new bulletin covering the full line of modernized beaver pipe tools which includes announcements of some entirely new items, all of which are illustrated and described.

**Packing**
The Darcoid Company, Inc., New York, is distributing a bulletin describing its line of Rodtite packing, featuring Type G, especially designed for service against propane, butane and other petroleum products.

**Lubricator**
Hills-McCanna Company, 2349 Nelson Street, Chicago, has issued a bulletin describing its recently developed force feed enclosed type lubricators including drawings, photographs and engineering information.

**Regulator**
Pittsburgh Equitable Meter Company, 400 North Lexington Avenue, Pittsburgh, has issued a new 12-page bulletin describing the Emco type ejector service regulator.

**Welding**
The Lincoln Electric Company, Cleveland, Ohio, has issued a 12-page booklet describing the Shielded Arc Process of electric welding and the results secured and Specification Bulletin No. 30, which is two pages of general specifications for motor driven welders.

**Welding**
Linde Air Products Company, 30 East 42nd Street, New York, is distributing publications as follows: Form 2238—eight pages on progress in bronze welding; Form 2298—24 pages on testing and qualifications of welders and Form 2444—eight pages on the use of welding in the maintenance of reciprocating parts.

**Tools**
Standard Electrical Tool Company, 1938 West 8th Street, Cincinnati, Ohio, has ready for distribution Catalog No. 37 for those interested in electric drills, grinders, buffings and polishing machines.

**Pneumatic Tools**
Ingersoll-Rand Company, Phillipsburg, N. J., announces publication of an eight-page bulletin "The World's Most Popular Tools," which includes first time listing of the company's new sizes of "Multi-Vane" drills, push-throttle screw drivers and nut setters.

**Anniversary Book**
The Harnischfeder Corporation, Milwaukee, Wisconsin, has published an anniversary book, "The Fiftieth Year," which reviews the company's long associating with the industrial field.

**Couplings**
Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania, has published a bulletin on its new general purpose couplings, designed for use in connection with gear-motors, speed reducers and other industrial drives.

**Pumps**
Worthington Pump and Machinery Corporation, Harrison, New Jersey, has issued Bulletin W-101-B2, describing its line of horizontal duplex piston pumps for general services, valve plate type, for handling liquids at pressures up to 125 pounds per square inch. Specifications and illustrations included.

**Centrifugal Pumps**
Worthington Pump and Machinery Corporation, Newark, New Jersey, has ready for distribution Bulletin No. W-318-B5, which describes the two-stage volute Type UB centrifugal pumps manufactured by the company.

**USE THIS COUPON**
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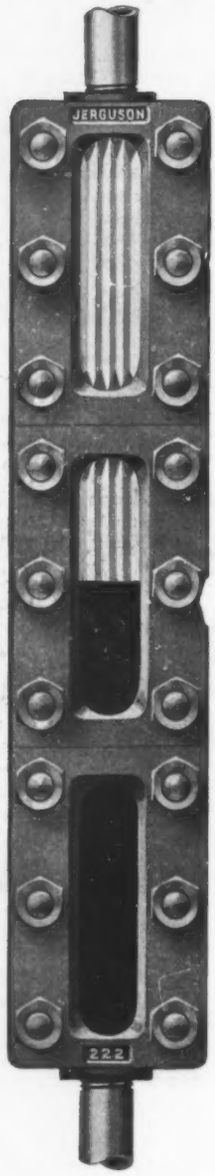


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**87 FELLSWAY**
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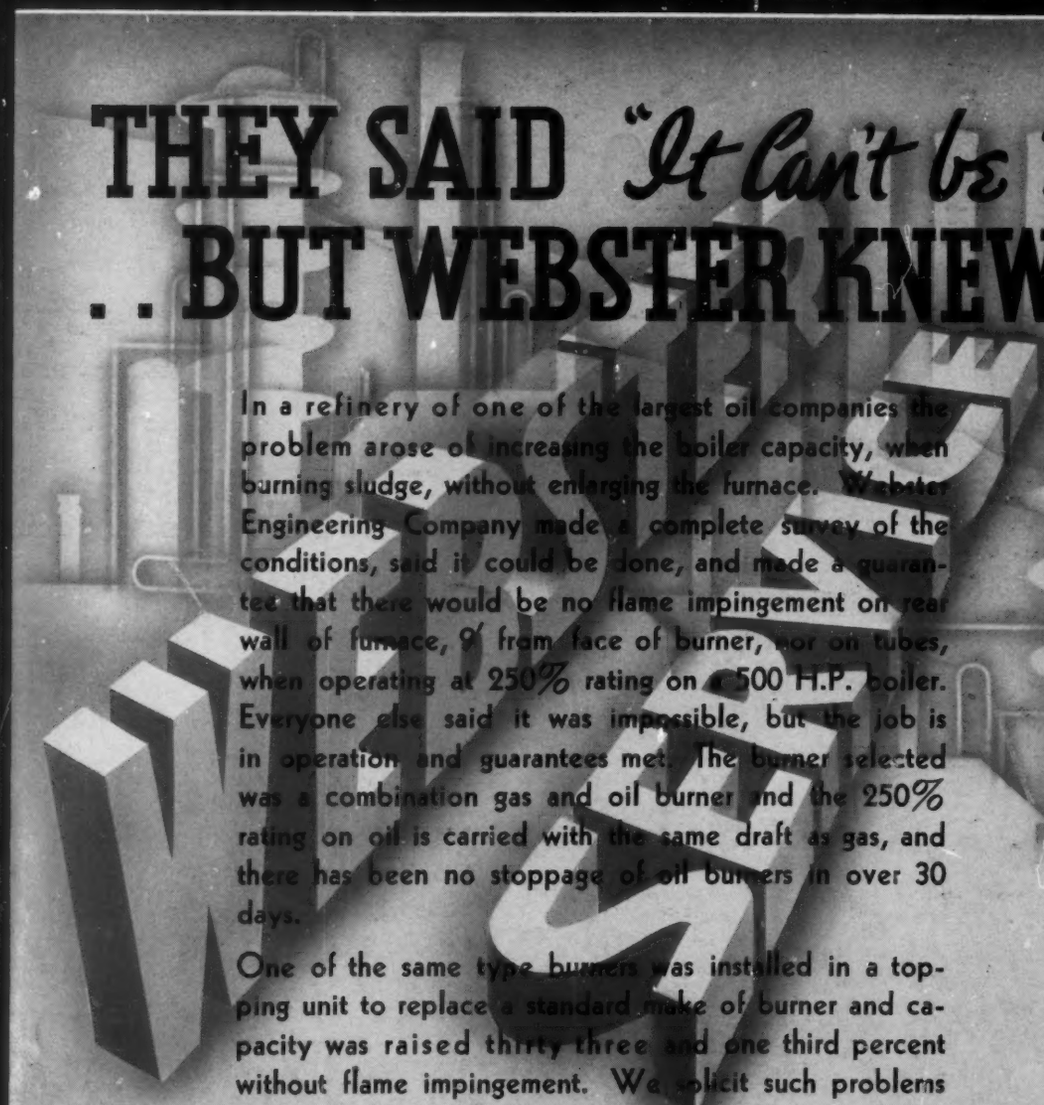
# THEY SAID *"It Can't be Done"* ..BUT WEBSTER KNEW HOW




In a refinery of one of the largest oil companies the problem arose of increasing the boiler capacity, when burning sludge, without enlarging the furnace. Webster Engineering Company made a complete survey of the conditions, said it could be done, and made a guarantee that there would be no flame impingement on rear wall of furnace, 9' from face of burner, nor on tubes, when operating at 250% rating on a 500 H.P. boiler. Everyone else said it was impossible, but the job is in operation and guarantees met. The burner selected was a combination gas and oil burner and the 250% rating on oil is carried with the same draft as gas, and there has been no stoppage of oil burners in over 30 days.

One of the same type burners was installed in a topping unit to replace a standard make of burner and capacity was raised thirty three and one third percent without flame impingement. We solicit such problems as these. . . . . .

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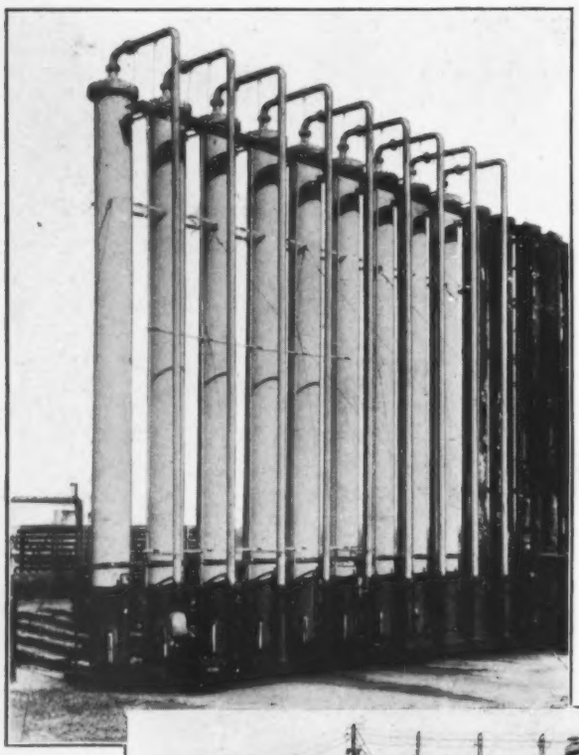
# Vogt

## HOMOWELD vessels for modern refineries

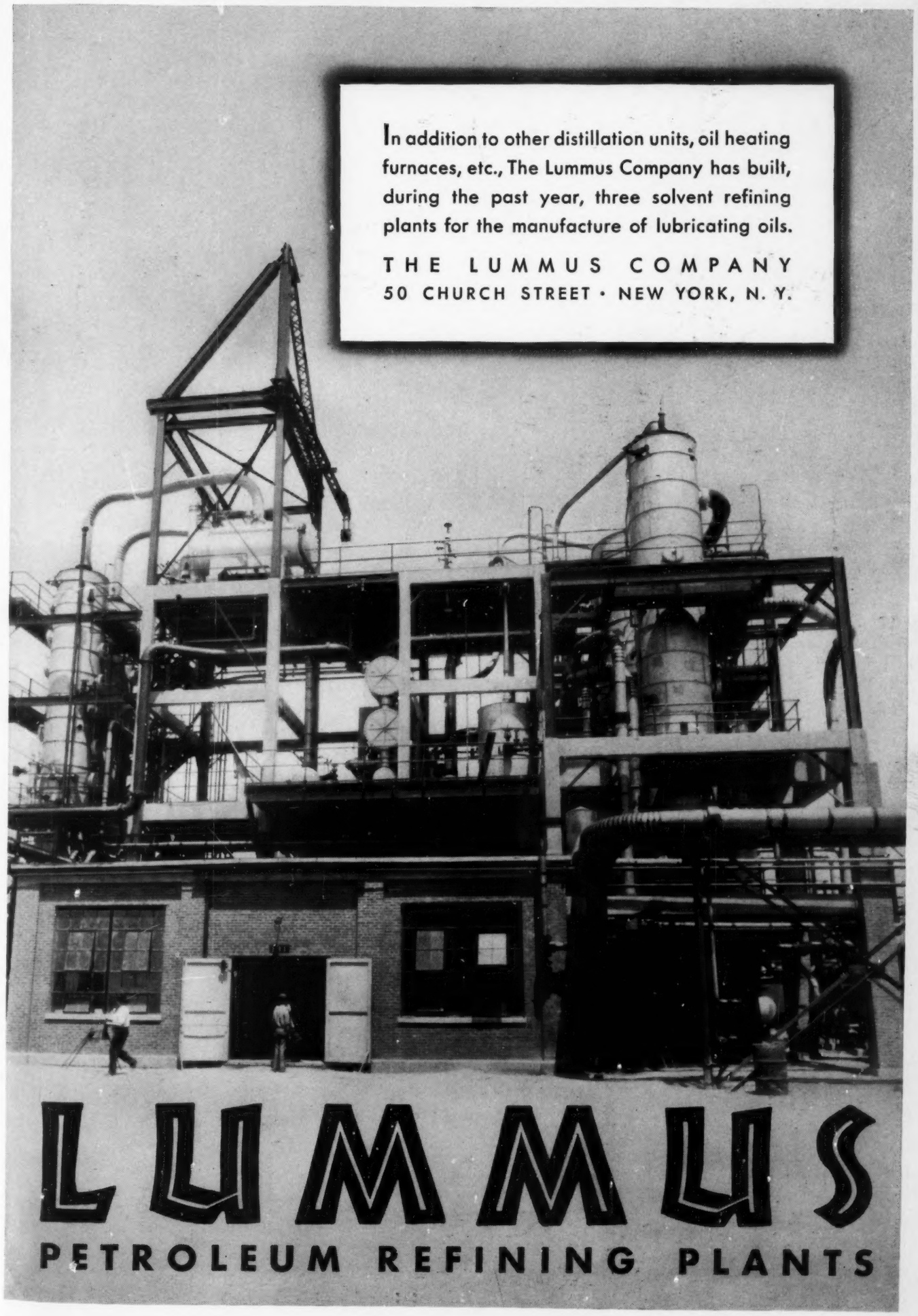


**Pressure Stills . . . Reaction Chambers**
**Absorption Towers . . . Heat Exchangers**
**Debutanizers . . . Expansion Chambers**
**Fractionating Towers . . . Bubble Towers**
**Reflux Towers . . . Soaking Drums**
**Accumulators . . . Condensers**
**Dephlegmators . . . Rectifiers**
**. . . and Cracking Chambers**

**HENRY VOGT MACHINE CO.**
Incorporated

| | | |
|---|---|---|
| LOUISVILLE | | KENTUCKY |
| New York | Chicago | Dallas |
| Philadelphia | | Cleveland |
| Kansas City | | Cincinnati |

Manufacturers of: Oil Refinery Equipment, Drop Forged Steel Valves and Fittings, Ice Making and Refrigerating Machinery, Water Tube Boilers, Heat Exchangers.


In addition to other distillation units, oil heating furnaces, etc., The Lummus Company has built, during the past year, three solvent refining plants for the manufacture of lubricating oils.
THE LUMMUS COMPANY
50 CHURCH STREET · NEW YORK, N. Y.
LUMMUS
PETROLEUM REFINING PLANTS

# *Long Economical Service is Built Into These...* LOADING VALVES

Plate 845
THROTTLE VALVE
Quick-Opening Type (need not be held open). Double wedge gates—high grade bronze. 1¼" to 3".

**McDonald Valves are made especially for use with oil and gasoline by a company with 77 years' metallurgical and manufacturing experience.**

**They are ground, packed and tested for oil and gasoline service . . . equipped with specially prepared packing and stuffing which eliminate leakage around the stem . . . designed and constructed for TIGHTNESS.**

**In a word, they are qualified in every detail to give long, hard and economical service.**

**That's why McDONALD VALVES continue to be, as they have been for years, the *first choice of the careful buyer.* To check over and replace faulty valves is one sure way to add to 1935 income. A special folder on valves will be mailed on request.**

(Patented)

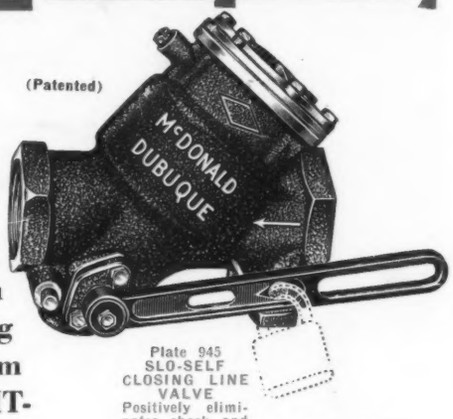



Plate 945
SLO-SELF CLOSING LINE VALVE
Positively eliminates shock and jar on pressure lines when suddenly closed. 2", 2½", 3".

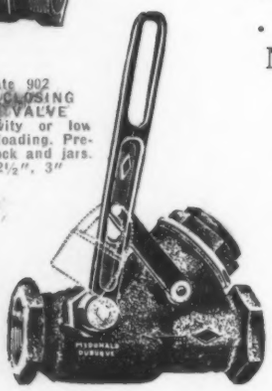



Plate 902
SELF-CLOSING LINE VALVE
For gravity or low pressure loading. Prevents shock and jars. 2", 2½", 3"

Plate 910
PRESSURE RELIEF VALVE
Smaller sizes used on gasoline meter dispensing systems; larger sizes for pumping installations at bulk plants. ¾" to 2½"

Plate 847
SELF-CLOSING ANGLE VALVE.
Especially adapted for use on Truck Tank Filling Pipes. Threaded for and permits full capacity of 2" pipe.

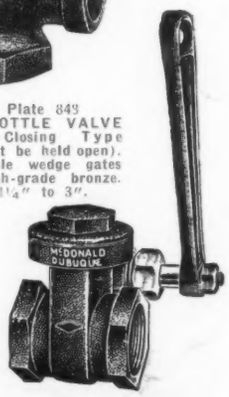



Plate 849
THROTTLE VALVE
Self-Closing Type (must be held open). Double wedge gates—high-grade bronze. 1¼" to 3".

**A. Y. McDONALD MFG. CO.**

*"The Home of the Swing Joint"*

**DUBUQUE, IOWA**

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Kansas City · Sioux City

*There's a McDonald Distributor Near You*

# McDONALD